

# GULF RESEARCH REPORTS

Supplement 1

June 1983

ISSN: 0072-9027



*Published by the*  
**GULF COAST RESEARCH LABORATORY**  
**Ocean Springs, Mississippi**

# Gulf Research Reports

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Volume 7

Issue 5 Volume 7, Supplement 1

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January 1983

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DOI: 10.18785/grr.07supp.01

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## Recommended Citation

Overstreet, R. M. 1983. Aspects of the Biology of the Spotted Seatrout, *Cynoscion nebulosus*, in Mississippi. Gulf Research Reports 7 (S1): 1-43. Retrieved from <http://aquila.usm.edu/gcr/vol7/iss4/1>

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**ASPECTS OF THE BIOLOGY OF THE SPOTTED SEATROUT,  
*Cynoscion nebulosus*, IN MISSISSIPPI**

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**ABSTRACT** About 3,000 specimens of the spotted seatrout from Mississippi Sound and adjacent water grouped by males and females had a nearly identical standard length (SL) versus total length (TL) relationship, although the equation for males in winter differed from that for those in other seasons. When investigating the SL-weight relationship, some differences occurred both among seasons and between sexes. Therefore, condition coefficients (K) were calculated to compare male and female groups according to their length and state of maturation on a seasonal basis. The hepatosomatic index (HSI) tended to increase with fish length, with relatively high values occurring in winter compared to low ones in summer when livers exhibited an abundance of lipid. Seasonal values of gonosomatic index (GSI) were typically less than those for HSI, except for ripe or nearly ripe fish. Males and females often concurrently exhibited contrasting values for both HSI and GSI. Females matured as short as 189 mm SL and males by 201 mm, and the percentage of gravid females in summer increased with increasing SL. By the time fish reached 40 cm, females constituted 85.7% of the sample from Mississippi Sound, not counting additional samples in 1982 that contained more males between 350 and 475 mm than females. Ovaries contained more oocytes than indicated in the literature. The largest estimate of oocytes over 30  $\mu$ m in diameter per female was ten and one-half million using a simple volumetric displacement method, or fifteen and one-half million when calculated using a gravimetric technique. Based on histological and other evidence, most individual fish in Mississippi apparently spawned periodically from April to September and even longer during years with appropriate temperature conditions. When gravid, fish tended to group in schools composed primarily of males or females. Tagging studies indicated that neither *C. nebulosus* nor *C. arenarius* moved farther than 25 km from their location of release. Both seatrouts hosted parasites that harm the host in natural water and culture conditions, that adversely affect their respective fisheries, and that potentially cause human distress. Several listed parasites had not been reported previously from the fishes.

**INTRODUCTION**

The spotted seatrout, *Cynoscion nebulosus* (Cuvier), supports an important commercial and recreational fishery in the southeastern United States. It constitutes one of the few commercially important fishes in that region that can spawn, develop, and spend its entire life in an estuarine environment. Consumers eat both the flesh and the ripe roe. Several aspects of the biology of this essentially nonmigratory fish that occurs from New York to Mexico depend on the fluctuating salinity and temperature, and, as pointed out by Tabb (1966), details of its biology from different estuaries are needed. Fish from different estuaries apparently spawn in their respective estuary, and few individuals migrate from those areas. Different growth-rates and tagged fish support that premise, as do blood-serum polymorphisms and, to a lesser extent differences in eye-lens proteins. Weinstein and Yerger (1976b) distinguished a separate subpopulation in each of seven estuaries from Texas to the east coast of Florida using electrophoretic methods and showed that the difference in those subpopulations increased with geographic distance. Because evidence favors distinct subpopulations from each estuarine system, because estuaries are vulnerable to environmental alterations detrimental to those subpopulations, and because the biological characteristics of the stock in Mississippi Sound are minimally understood (Etzold and Christmas 1979), this study was undertaken to assess the

Mississippi stock.

Most of the data for this study was collected from mid-1978 to mid-1980. Atypically low salinity levels over long periods, low temperatures occurring suddenly, and possibly other factors resulted in few available fish during much of the study period. In fact, local fish houses and restaurants had no local spotted seatrout for many continuous months. Nevertheless, collections were made and data from these are compared and often combined with previously collected data. I include also some data on tagged and infected *C. arenarius* Ginsburg, possibly a subspecies of *C. regalis* (Bloch and Schneider) (see Weinstein and Yerger 1976a). Information on food contents of three seatrout species in Mississippi occurs separately (Overstreet and Heard 1982). References to comparative biological data on *C. arenarius* are listed by Moffett et al. (1979), and Shlossman and Chittenden (1981) provided the most extensive report on that species.

**MATERIALS AND METHODS**

Samples of the spotted seatrout were gill-netted, trammel-netted, seined, or caught by hook and line on a monthly basis from August 1978 to December 1980. Added to data describing those samples are data on fish previously collected for investigations on specific parasites and stomach contents (Overstreet 1977, Deardorff and Overstreet 1981, Overstreet and Heard 1982). Those fish not measured, tagged, and released were covered with ice and transferred to the laboratory for detailed analyses. Reliable commercial and recreational fishermen caught some individuals, and Gulf Coast

Research Laboratory (GCRL) personnel collected the rest. Most came from Mississippi Sound; those from other localities are specified in the text.

Fish tags used on a few fish before 1978 were commercially-produced dart tags inserted with a Dennison tagging gun, but these apparently were expelled, or the glue binding the labeled streamer to the anchor did not hold, or the base of the tubing split. Sackett and Hein (1979) noted that after 90 days in a pond, only about 60% of tagged seatrout retained that type of tag, and 27% of the remaining tags were broken or split. Consequently, internal anchor tags were used exclusively after 1977. Two sizes of labeled, laminated, cellulose, acetate anchors directed those who found them to provide GCRL pertinent information (Figure 1). The large anchor, 26 by 7 mm, had red, green, or yellow strips of size 18 polyvinyl chloride insulation tubing about 13 cm long inserted through a centrally located hole. For small fish, 15 by 5 mm labels (both sizes produced by Howitt Plastic Company, now Floy Tag & Manufacturing, Inc.) were fitted with about 8 cm of size 24 tubing. This pliable tubing trailed from a fish after the unit was inserted through the wall of the body cavity. The proximal end of the tubing was expanded on a hotplate, the distal oblique end pulled through the hole in the anchor, and any remaining hole in the proximal end plugged with paraffin. After being inserted through a ventral incision in the fish, the tag, by means of the tubing, was twisted until the anchor lay perpendicular to the slit without binding any internal organs against the cavity wall. This incision paralleled the fish's vertebral column, was located slightly off-midline and a short distance anterior to the anus, and measured about 1 mm wider than the width of the tag. If conditions were unsafe to release tagged fish because of nets, predators, or other reasons, personnel temporarily retained them in large, aerated, plastic containers.

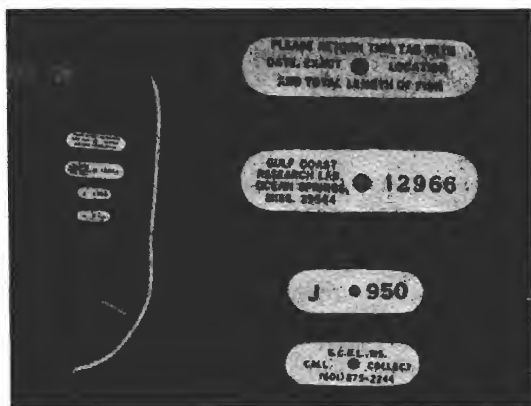


Figure 1. Internal body-cavity anchor tags and close-up of two-sided label. The small-sized tag is used for juvenile seatrouts as well as individuals of shorter fishes.

Striped bass, Atlantic croaker, and other fishes properly tagged and held in GCRL raceways did not shed tags after several months, their incisions healed rapidly, and they showed no complications from the tagging operation.

Once the standard length (SL) and total length (TL) were measured to the nearest millimeter (mm) and weight obtained to the nearest 0.05 grams (g), the fish was cut open, its viscera removed, and the fish reweighed. Unless indicated otherwise, all lengths are SL even though SL is occasionally stipulated. Gonads and liver were each blotted to remove excess liquid and weighed to the nearest 0.01 g; also, their volumetric displacement of water was noted to the nearest 0.1 milliliter (ml) using 5 to 2000 ml graduated cylinders. For females, an aliquot of ovarian tissue including a small amount of tunic approximating 0.06 or 0.12 g was weighed to the nearest 0.002 g (a few weighed to the nearest 0.001) and its displacement of water in a 5 ml cylinder recorded to the nearest 0.01 ml. That tissue was fixed and stored in Gilson's fluid (Simpson 1951).

To estimate fecundity, the Gilson's fluid was decanted from the vial with the ovarian aliquot and replaced with 1/3 vial of distilled water. After being stored in Gilson's fluid for at least 3 to 5 months, the eggs easily separated from each other without modifying their shape when shaken for about 30 to 60 seconds in a mechanical vibrator. Eggs were then spread evenly over a gridded, 88 mm-diameter petri-dish and counted within five 10.89 mm<sup>2</sup> grids (including those eggs overlapping two sides). If the counts were not similar, the eggs were respread more evenly and counted again. If counts were similar, their sum was used to calculate the estimated number in the aliquot which in turn was used to calculate the estimated number in the ovaries (density of oocytes appeared similar in both ovaries from a fish) using both volumetric displacement and gravimetric techniques. The ratio between the number of eggs in the aliquot and the total number in both ovaries was assumed to be roughly proportional to both the measured displacement of aliquot to that of ovaries or the measured weight of aliquot to that of ovaries.

After fecundity was estimated from an aliquot of representative fish, approximately 100 of the oocytes were measured using an ocular micrometer at 40X magnification. These values for oocytes from each fish were grouped by stage of maturation of fish and used to construct length-frequency graphs. Table 1 defines the arbitrary stages of maturation for both males and females determined by gross examination.

Representative tissues of gonads and suspected diseased tissues were fixed in 10% phosphate-buffered formalin, processed for paraffin-embedded sections, and routinely stained using Harris's hematoxylin and eosin Y. Occasionally, special staining methods (Luna 1968) were used to assess specific features.

The location of each fish was recorded as precisely as



TABLE 1.

Gross appearance of gonads in *Cynoscion nebulosus* relative to arbitrary stages of maturity.

Stage	Gonad	Fresh color	Color after 6 to 15 hr	Length of gonad as % of body cavity	Amount of adjacent lipid deposit	Remarks (without use of microscope)
I. Virgin	ovary	colorless to grey	light orange to rust	10-15	very little	appears similar to mesentery
	testes	very light grey	same	10-15	none	
II. Maturing Virgin	ovary	colorless to grey	dark orange	15-25	very little	
	testes	light grey	same	20-30	none	
III. Developing and resting	ovary	grey or light orange	very dark orange	45-55	moderate	blood vessels conspicuous
	testes	grey to creamy	same	45-55	little	blood vessels not conspicuous
IV. Developing	ovary	dark orange	reddish	65-70	more than in III	blood vessels wider than in III
	testes	creamy	same	60-70	small	blood vessels very thin or not conspicuous
V. Gravid	ovary	yellow to light yellow	same	85-95	less than in IV	blood vessels maximal diameter
	testes	creamy	same	50-95	small	blood vessels not apparent, testes wide
VI. Spawning	ovary	yellow	same	85-95	little or none	blood vessels still large and reddish, ovary widest
	testes	creamy to white	same	55-95	small	blood vessels not apparent, testes widest
VII. Spent	ovary	light yellow	same	75-80	none	blood vessels brownish, ovary flaccid, fluid expelled with pressure
	testes	creamy to grey	same	55-95	small	width reduced, a little fluid can be expelled

possible as was the temperature and salinity of the water at that location. Additionally, biweekly or triweekly measurements of temperature and salinity of water were monitored from off the GCRL pier at about 8:00 a.m. Initially, measurements were taken with a hand-held thermometer and an American Optical Co. temperature-compensated refractometer, but later in the study they were taken with a Yellow Spring Instrument Co. conductivity meter (YSI model 33, S.C.T.).

Different indices and statistical methods are indicated or explained in the text under the appropriate sections. Procedures for the analysis of covariance (ANOC) follow those by Snedecor and Cochran (1967) and Dixon and Massey (1957) and those to test for homogeneous variances are for Cochran's test (Dixon and Massey 1957) and Bartlett's test (Ostle and Mensing 1975).

#### RESULTS AND DISCUSSION

##### Temperature and Salinity Data

Biweekly or triweekly measurements of temperature and

salinity of Davis Bayou were grouped on a monthly basis, and the average values are graphed in Figure 2. They usually represented well both surface and bottom water from the northern Mississippi Sound nearshore areas as determined by comparisons with data collected by others at GCRL. To accentuate the severity of environmental conditions that took place during the primary period of this study, winter temperatures dropped below freezing in 1978, 1979, and 1980. Between 22 February and 13 August 1979 recorded salinity values remained below 10 ppt, seldom surpassed 6 ppt, and mostly stayed at 1 ppt or less in April, May, and part of July. Hurricane Bob passed through on 11 July 1979 and Hurricane Frederic on 12 September 1979. In 1978, readings did not surpass 10 ppt until mid-July and then rarely until September. The low salinity probably acted as the single most influential factor in the low availability of spotted seatrout during most of the study.

##### Standard Length-Total Length Relationship

To predict total length (TL) from standard length (SL), the general regression equation  $TL = a(SL)^b$  was used. To

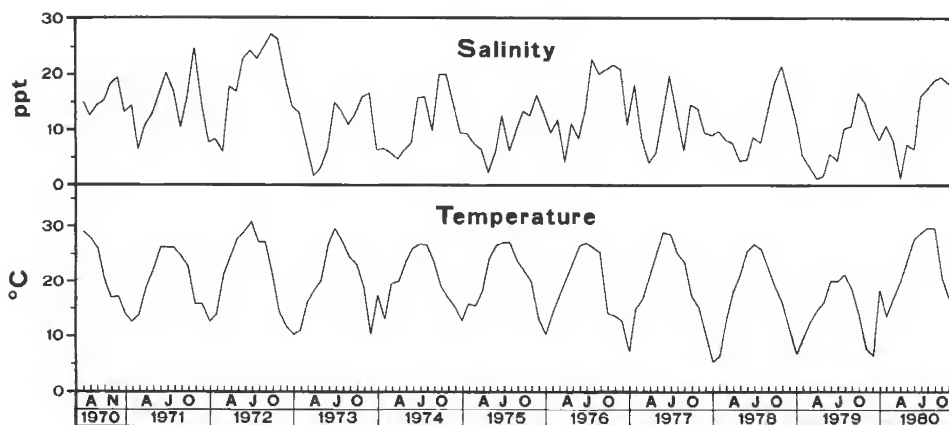


Figure 2. Monthly averages of temperature and salinity of water from 1970 through 1980 monitored bi- or triweekly from GCRL.

determine if equations differed according to sex and season, I used two methods. In the first, estimates of differences among equations were apparent by comparing calculated measurements of specific-sized individuals from each different group. The total length (TL) values calculated for a 300 mm SL fish in each group revealed some differences as shown in Table 2. In the second method, analysis of covariance (ANOC) was used to compare regression equations (Table 2) for males versus females on a seasonal basis and to compare equations for paired combinations on a seasonal basis for males and for females. When comparing equations between sexes, only those representing winter data had homogeneous variances. Even during this season when differences between sexes appeared greatest, the means did not differ ( $F = 2.72 < F_{.05[1,401 \text{ df}]} = 3.86$ ) and a single regression line could represent data for both sexes ( $F = 2.25 < F_{.05[2,400 \text{ df}]} = 3.02$ ). In contrast, the means for males in winter differed from those for males during other seasons ( $F = 4.66 - 7.24 > F_{.05[1,424 - 1,245 \text{ df}]} = \sim 3.86$ ) and one regression line would not represent any of the specific pairs ( $F = 4.70 - 5.69 > F_{.05[2,423 - 1,244 \text{ df}]} = \sim 3.00$ ), even though variances for data in winter versus summer were not homogeneous. The slopes differed for regression lines in winter versus spring and autumn, but not for that line representing all seasons combined ( $F = 4.70, 4.35 > F_{.05[1,423 - 537 \text{ df}]} = 3.86$ ,  $F = 2.54 < F_{.05[1,1244 \text{ df}]} = 3.85$ ). Differences for means of data comparing males in winter with those for all seasons combined can be explained. The slopes were the same, but their intercepts along the Y (TL) axis differed ( $F = 6.84 < F_{.05[1,1245 \text{ df}]} = 3.85$ ). A similar explanation can describe the regression lines for females in spring versus autumn. The means differed ( $F = 4.83 > F_{.05[1,1058 \text{ df}]} = 3.85$ ) and separate regression lines were necessary to represent them ( $F = 3.54 > F_{.05[2,1057 \text{ df}]} = 3.00$ ), but the linear slopes ( $F = 0.003 < F_{.05[1,1058 \text{ df}]} = 3.85$ ) did not differ ( $F = 2.23 < F_{.05[1,1057 \text{ df}]} = 3.85$ ). The difference in means can be explained by a difference in intercepts ( $F = 4.83 > F_{.05$

$[1,1058 \text{ df}] = 3.85$ ). Variances were homogeneous for data representing females in spring versus winter (and all seasons combined) and for males in spring versus autumn (and all seasons combined), but their means did not differ and a single regression line could be used to represent all data for the pairs. Variances were not homogeneous for the other combinations.

In addition to calculating the regression equations with TL as the dependent variable, I calculated and listed them using SL as the dependent variable and TL as the independent one (Table 2). These do not differ considerably from their counterparts as can be seen by calculated values for 300 mm SL fishes, but they should be used by those conducting comparative studies based on SL as the dependent variable. Also, for comparative assessments, equations are listed using logarithmically transformed data. Like their nontransformed counterparts, these also have high correlation coefficients and narrow confidence limits about the slopes.

Large samples of spotted seatrout have been measured also from Louisiana and Texas, and values for the fitted equations for those data occur also in Table 2. Calculated TL values for a 300 mm SL fish from those collections are slightly larger than for fish in the Mississippi collection. That calculated value for a fish in a collection from Georgia is considerably larger, but it is an extrapolation because the small sample included no fish over 60 mm. Moffett (1961), mostly on the basis of fish between 11 and 32 cm, found a linear relationship for corresponding data from the spotted seatrout in west Florida. He calculated TL by multiplying SL by 1.22; using that method, a 300 mm SL fish would be 366 mm long, or much longer than the average TL of a fish in Mississippi. In the above cases, probably neither method produces reliable comparisons.

#### Standard Length-Weight Relationship

The general regression equation of the form  $\text{Log } W = \text{Log } a + b (\text{Log } \text{SL})$  to make data linear was fitted to data according to sex, stage of maturity, length group, season, and

TABLE 2.

Standard length-total length relationships for *Cynoscion nebulosus* collected in Mississippi Sound from 1972 through 1980 compared with those from other localities (N = number of fish examined; a = TL (or SL) axis-intercept; b = slope; and r = correlation coefficient).

Sex	Standard length range in mm	N	TL = a + b (SL)	95% confidence interval of b	r	Calculated TL for a 300 mm SL fish in mm	Geographical locality	Reference
Female	39–544	1680	Log TL = 0.1608+0.9620 (Log SL)	0.9599–0.9640	0.9990	349.8	Mississippi Sound	Present study
Male	40–465	1089	Log TL = 0.1623+0.9611 (Log SL)	0.9576–0.9646	0.9981	349.2	Mississippi Sound	Present study
Female	39–544	1680	TL = 10.6586+1.1284 SL	1.1250–1.1317	0.9981	349.2	Mississippi Sound	Present study
Male	40–465	1089	TL = 10.1648+1.1292 SL	1.1239–1.1344	0.9970	348.9	Mississippi Sound	Present study
Female Winter	75–460	245	TL = 9.7670+1.1290 SL	1.1252–1.1328	0.9996	348.5	Mississippi Sound	Present study
Male Winter	92–418	159	TL = 11.4230+1.1168 SL	1.0946–1.1391	0.9921	346.5	Mississippi Sound	Present study
Female Spring	92–544	427	TL = 10.7260+1.1258 SL	1.1183–1.1333	0.9976	348.5	Mississippi Sound	Present study
Male Spring	100–419	268	TL = 7.7890+1.1386 SL	1.1315–1.1456	0.9987	349.4	Mississippi Sound	Present study
Female Summer	39–453	374	TL = 14.3090+1.1183 SL	1.1053–1.1314	0.9935	349.8	Mississippi Sound	Present study
Male Summer	40–412	280	TL = 15.7770+1.1099 SL	1.0928–1.1271	0.9915	348.7	Mississippi Sound	Present study
Female Autumn	82–518	634	TL = 9.8480+1.1321 SL	1.1277–1.1365	0.9988	349.5	Mississippi Sound	Present study
Male Autumn	76–465	382	TL = 9.3000+1.1336 SL	1.1292–1.1380	0.9993	349.4	Mississippi Sound	Present study
Female	39–544	1680	SL = -8.3544+0.8828 TL <sup>1</sup>	0.8802–0.8854	0.9981	349.3	Mississippi Sound	Present study
Male	40–465	1089	SL = -7.4654+0.8802 TL <sup>1</sup>	0.8762–0.8843	0.9970	349.3	Mississippi Sound	Present study
Combined	8–60	20	TL = 1.020+1.224 SL			368.2 <sup>2</sup>	Coastal Georgia	Jorgenson and Miller (1968)
Combined	21–629	1208	SL = -3.8832+0.8653 TL <sup>1</sup>		0.9946	351.2	South-central Louisiana	Hein et al. (1980)
Combined	36–744	9857	TL = 11.804+1.138 SL	1.136–1.140	0.997	353.2	Texas bays	Harrington et al. (1979)

<sup>1</sup>Note TL and SL reversed. <sup>2</sup>Sample-range did not include fish 300 mm long.

year. Values for fitted equations of data grouped by sex and season regardless of year, as well as by sex regardless of season, had a correlation coefficient (r) of at least 0.99 and appear in Table 3. Because readers may wish to compare those data with those from other reports and methods, other available equations are presented. The same data used for Table 3 are additionally transformed with natural rather than common logarithms, and the corresponding equations are listed in Table 4. Also listed there are equations from non-transformed, curvilinear data to illustrate the considerable difference in correlation coefficients and calculated weights when compared with those from linear data. Additionally, listed comparative equations for fish from other geographic areas suggest Mississippi fish may be heavier than fish of the

same length from most cited collections.

Table 3 shows that both males and females of a given length weigh more during spring when rapid development for reproduction occurs. Also in spring, but not in other seasons, calculated weight for a 300 mm female is greater than that for a corresponding male.

Corresponding equations calculated using natural logarithms had similar correlation coefficients, with calculated weights for a 300 mm fish differing by +1.3 to -1.5 g and averaging only -0.1 g. When SL rather than weight served as the dependent variable, correlation coefficients for the corresponding equations were identical, but calculated weights for a 300 mm fish were consistently more, ranging from 0.8 to 5.8 g and averaging 2.3 g. Most of that difference,

TABLE 3.

Standard length-weight relationships for 2,770 individuals of *Cynoscion nebulosus* collected in Mississippi Sound from 1972 through 1980 by sex and season (N = number of fish examined; Log a = Log W (or Log SL) axis-intercept; b = slope; and r = correlation coefficient).

Season	Sex	Standard length range in mm	N	Log W = Log a + b (Log SL)				Calculated weight for a 300 mm SL fish in g
				Log a	b	95% confidence interval of b	r	
Winter	Female	75-460	246	-4.9599	3.0526	3.0312-3.0740	0.9985	399.7
Winter	Male	92-418	159	-4.8990	3.0286	2.9648-3.0924	0.9912	401.1
Spring	Female	92-544	424	-5.0362	3.0922	3.0711-3.1134	0.9975	420.3
Spring	Male	100-419	266	-5.1024	3.1214	3.0949-3.1480	0.9975	426.3
Summer	Female	39-453	374	-4.5878	2.9071	2.8680-2.9461	0.9914	410.6
Summer	Male	40-412	280	-4.6472	2.9219	2.8751-2.9688	0.9909	389.7
Autumn	Female	82-518	639	-4.9466	3.0481	3.0318-3.0645	0.9976	401.7
Autumn	Male	76-465	382	-4.9463	3.0508	3.0314-3.0703	0.9980	408.2
Combined	Female	39-544	1683	-4.9472	3.0516	3.0402-3.0629	0.9970	409.2
Combined	Male	40-465	1087	-4.9466	3.0510	3.0343-3.0676	0.9958	408.4
Log SL = Log a + b (Log W)								
Winter	Female	75-460	246	1.6271	0.3266	0.3243-0.3289	0.9985	400.5
Winter	Male	92-418	159	1.6306	0.3244	0.3176-0.3312	0.9912	406.9
Spring	Female	92-544	424	1.6327	0.3217	0.3195-0.3239	0.9975	421.6
Spring	Male	100-419	266	1.6384	0.3188	0.3161-0.3215	0.9975	427.4
Summer	Female	39-453	374	1.5927	0.3381	0.3336-0.3427	0.9914	412.9
Summer	Male	40-412	280	1.6050	0.3360	0.3306-0.3414	0.9909	394.1
Autumn	Female	82-518	639	1.6266	0.3265	0.3248-0.3283	0.9976	402.7
Autumn	Male	76-465	382	1.6241	0.3265	0.3244-0.3286	0.9980	409.8
Combined	Female	39-544	1683	1.6260	0.3257	0.3245-0.3269	0.9970	410.4
Combined	Male	40-465	1087	1.6275	0.3250	0.3233-0.3268	0.9958	411.4

TABLE 4.

Standard length-weight relationships for *Cynoscion nebulosus* collected from different localities and calculated using different forms of the regression equation (ln = natural logarithm).

Sex	Season	Length range in mm	N	Equation	r	Calculated weight for a 300 mm SL fish in g	Geographical locality	Reference
F	Winter	75-460 SL	238	ln W = -11.4000+3.0484 (ln SL)	0.9985	398.4	Mississippi Sound	Present study
M	Winter	92-418 SL	144	ln W = -11.2720+3.0269 (ln SL)	0.9903	400.5	Mississippi Sound	Present study
F	Spring	92-544 SL	425	ln W = -11.6020+3.0935 (ln SL)	0.9974	421.0	Mississippi Sound	Present study
M	Spring	100-419 SL	264	ln W = -11.7522+3.1221 (ln SL)	0.9976	426.5	Mississippi Sound	Present study
F	Summer	39-453 SL	368	ln W = -10.6100+2.9151 (ln SL)	0.9919	410.4	Mississippi Sound	Present study
M	Summer	40-412 SL	281	ln W = -10.6970+2.9213 (ln SL)	0.9909	389.8	Mississippi Sound	Present study
F	Autumn	82-518 SL	628	ln W = -11.3860+3.0473 (ln SL)	0.9976	401.5	Mississippi Sound	Present study
M	Autumn	76-465 SL	372	ln W = -11.4132+3.0556 (ln SL)	0.9981	409.7	Mississippi Sound	Present study
F	Combined	39-544 SL	1649	Log W = -5.4471+3.1681 (Log TL)	0.9967	408.6 <sup>1</sup>	Mississippi Sound	Present study
M	Combined	40-465 SL	1060	Log W = -5.4608+3.1742 (Log TL)	0.9970	408.8 <sup>1</sup>	Mississippi Sound	Present study
F	Combined	39-544 SL	1659	W = -483.1290+3.2522 (SL)	0.9277	492.5	Mississippi Sound	Present study
M	Combined	40-465 SL	1061	W = -355.5150+2.6350 (SL)	0.9348	435.0	Mississippi Sound	Present study
F	Combined	203-546 SL	97	Log W = -4.4160+2.8442 (Log SL)	0.9207	426.0	Chandeleur Is., LA	Present study
M	Combined	193-394 SL	78	Log W = -4.2650+2.7710 (Log SL)	0.9361	397.3	Chandeleur Is., LA	Present study

TABLE 4. (Continued)

Standard length-weight relationships for *Cynoscion nebulosus* collected from different localities and calculated using different forms of the regression equation ( $\ln$  = natural logarithm).

Sex	Season	Length range in mm	N	Equation	r	Calculated weight for a 300 mm SL fish in g	Geographical locality	Reference
		49-902 TL	9498	Log W = -5.192+3.062 (Log TL)	0.988	407.4 <sup>1</sup>	Texas bays	Harrington et al. (1979)
		21-138 SL	35	Log W = -4.62811+2.91740 (Log SL)	0.996	396.9	Upper Galveston Bay, TX	Matlock and Strawn (1976)
		21-629 TL	1208	Log W = -5.4215+3.1542 (Log TL)	0.9941	405.2 <sup>1</sup>	South-central Louisiana	Hein et al. (1980)
			49	Log W = -4.39+2.7995 (Log SL)		350.5		Vetter (1977)
	Combined		307	Log W = -5.3333+3.1131 (Log TL)		391.2 <sup>1</sup>	Ft. Myers and Cedar Key, FL	Moffett (1961)

<sup>1</sup>Using value adjusted to SL from conversion factor of work cited.

however, could be attributed to the specific equations for males in winter and summer.

The common logarithmic regression equations could be analyzed with ANOC between males and females on a seasonal basis because data for all four seasons, separate and grouped, were linear and variances were homogeneous. Means between sexes differed only for summer and autumn samples ( $F = 48.74, 6.84 > F_{0.05[1,651] - 1,018 df} = 3.86$ ), and one regression line could not represent both sexes ( $F = 24.45, 3.44 > F_{0.05[2,651] - 1,017 df} = 3.02$ ). In both cases, however, slopes for both regression lines were the same ( $F = 0.23, 0.04 < F_{0.05[1,650] - 1,017 df} = 3.86$ ); the regression for the means in both cases was linear ( $F = -0.03, 0.03 < F_{0.05} = 3.86$ ), but with a difference in intercepts ( $F = 48.77, 6.81 > F_{0.05} = 3.86$ ).

Comparing regression equations based on data from individual seasons and also on data from combined seasons for each sex revealed differences for all combinations except those for males in winter versus those in summer, autumn, and all seasons combined and those for differences in means in females from winter versus summer. Means for the other cited comparisons, most of which involved spring regressions, differed ( $F = 5.33 - 48.29 > F_{0.05} = 3.85$ ), and one regression line could not be used to represent the pairs ( $F = 14.44 - 50.29 > F_{0.05} = 3.02$ ). The linear slopes of those regression lines differed ( $F = 6.44 - 71.37 > F_{0.05} = 3.85$ ). Variances for SL and weight measurements, however, were not homogeneous for the following comparisons: female spring versus autumn and winter; male summer versus spring, autumn and combined; male autumn versus spring and combined. Nevertheless, the means for length and weight of all of those comparisons, except males in summer versus spring, differed when compared using Snedecor and Cochran's (1967) test for means when variances are unequal.

The usefulness of fitted regression equations can and has often been questioned (e.g., Ricker 1973). Values depend on whether and how data are collected and pooled. Data from Mississippi illustrate that one should not calculate weight of fish caught during specific periods, such as spring, using an equation derived from data that had been pooled from one or more entire years. Equations derived from three year-groups, 1980, 1979, and 1972-1978, usually differed little (much less than those from seasonal groups) when like-groups of similar sample-size were compared. Consequently, they were pooled. However, a small sample-size and a skewed frequency of fish in various length-groups often influenced values considerably, neither producing a fit approaching that for grouped data nor having a significant correlation coefficient.

The equations without logarithmic transformation, and consequently neither linear nor meeting the necessary assumptions, had low  $r$  values as well as produced unrealistic calculated weights. Transformed linear data based on relatively small samples from Chandeleur Islands also contributed to relatively low  $r$  values (0.92 to 0.94). Using females from this group as examples to illustrate the wide range of values producing the fits, I calculated that a 300 mm SL female in spring would weigh 491.3 g ( $N = 32$ ) compared to 386.6 g ( $N = 14$ ) in summer and 400.7 g ( $N = 51$ ) in autumn. The 95% confidence interval about a  $b$  (slope) value of 2.9881 in spring ranged from 2.0311 to 3.9451 and the others had similarly large ranges. Adkins et al. (1979) provided length-weight frequency graphs for males and females with calculated curves using a different transformation and obtained  $r$  values of 0.926 and 0.927 for 429 females and 147 males from an area in Louisiana adjacent to Mississippi. Large sample sizes of fish from Texas and Louisiana (Harrington et al. 1979, Hein et al. 1980) produced pooled values



similar to those in Mississippi. However, as seen by seasonal data from Mississippi, even when data for fish are pooled and a fit has a high correlation coefficient, the equation still may be inadequate for comparative purposes. For that reason, K values for groups of fish broken down by year, season, length of fish, stage of maturation, and sex are presented below.

*Condition Coefficient, Liver Weight, and Gonad Weight*

The condition coefficient,

$$K = \frac{W \times 10^5}{SL^3},$$

often represents a more practical means to compare length-weight relationships of fish-groups restricted by length, stage of maturity, and certain other parameters than does the regression equation. Table 5 shows that fish-groups from 22 to 40 cm long had relatively high K values in spring and low ones in winter. Fish over 30 cm in summer, a period when most have released large quantities of gametes, also had a low K. Females generally had a higher K than their male counterparts. Differences in K among corresponding groups in different years as well as those of individuals within certain specific groups as indicated by high standard errors (SE) illustrate variability. Table 6 combines the data for all years, and Table 7 lists bimonthly values based on total length ( $K_{TL}$ ) for use as comparisons with those by other authors.

Tables 8 and 9 use the same data as in Table 5, but group individual values according to stage of maturity rather than by length of fish. Seasonally, the K values for grouped 1972–1980 data (Tables 6 and 9) portray a more gradual increase by stage of development than by length. On the other hand, this trend is not apparent from 1979 or 1980 data (Tables 5 and 8).

The hepatosomatic index,

$$HSI = \frac{\text{Liver weight} \times 100}{\text{Total fish weight}},$$

is listed on the same tables as K values. It tends to increase with fish-length, with relatively high values in winter and relatively low ones in summer (Tables 5 and 6). In several cases, the HSI for females tended to be larger than that for their male counterparts in the same group, especially in large fish (Table 6). From Mississippi Sound, the high HSI values of 4.15 and 3.95 for females and 3.46 and 3.44 for males occurred during winter. An immature fish had an even higher value. A male and female from Chandeleur Islands had HSI values of 4.46 and 4.03 during autumn. Furthermore, HSI values among grouped samples often varied more than corresponding K values for the same group.

In addition to being relatively small, livers of numerous fish during summer months, specifically apparent in May, June, and August 1973, and in August 1979, exhibited extensive lipid vacuolization. These cream-colored livers often contained separate yellowish focal areas, and they contrasted

conspicuously with the brownish-red colored livers that were noted during most of the year. Of 85 of these fish with fatty livers, only 19 were males, and all those with gross yellowish areas were females. The 85 comprised males and females from 128 to 441 mm long, mostly in stages III to V, but a few in stages I and II. Fatty deposits of adipose tissue in the body cavity appeared pronounced in most fish during autumn and winter.

Seasonal variation in the gonosomatic index,

$$GSI = \frac{\text{Weight of gonads} \times 100}{\text{Total weight of fish}},$$

showed an increase by fish-length and by stage of maturity, as well as reflected pronounced seasonality (Tables 10 and 11). The ovary increased in relative weight more than the testes during spring and summer when maturation and spawning took place. Few fish had conspicuously high GSI values. One stage VI 326 mm female caught 21 May 1980 and releasing ova when handled had a GSI = 10.01, and that for a stage V 200 mm female caught 14 July 1976 was 12.37. Values of GSI were often higher in 1979 than in corresponding seasons during 1980. Grimes and Huntsman (1980) discussed some of the problems inherent in using a gonad-index.

Variation among relative weights of both liver and gonads in the larger, more mature fish is expressed by the high SE's (Tables 5, 9, 10, and 11). That variation plus seasonal differences also appear evident in fitted seasonal regression equations relating either liver or gonad weights with fish weight (Tables 12 and 13). In spite of most r values being less than 0.95, fitted equations are presented. Calculated values from the equation, especially as exemplified by those from early and late stage gonads of summer females (Table 13), do not always take maturation into account, but they do allow comparisons by seasons and sex of fish. When regression equations for both gonad and liver weights on fish weight were fit for summer males and summer females separated into groups of 40 to 249 mm and 250 to 453 mm, the r values were much lower than those for the same fish grouped by developmental stages as listed in Tables 12 and 13. Because samples of fish collected in different seasons and different years comprised different numbers of fish in specific length- and developmental stage-groups and because members of these groups ranged widely in length, data from representative fish in two restricted length-groups provide a more meaningful comparison (Table 14). Regardless of similarity in stage and size, considerable variation still existed. Nevertheless, Table 14 shows that variation occurred seasonally as indicated earlier; that little relative difference existed between liver weight in males and females, especially large individuals; and that the liver during much of the year weighed much more than the gonads. A 368 mm male in spring had an 18.25 g liver and a 2.05 g testes. Difference in weight between ovaries and testes became especially disparate in gravid fish because of the heavy ovaries.

TABLE 5.  
Seasonal condition coefficient (K[standard length]) and hepatosomatic Index (HSI) of *Cynoscion nebulosus* from Mississippi Sound relative to year, sex, and length of fish.

		Standard length in millimeters											
		<140			140-219			220-299			300-399		
Sample size		K±SE	HSI±SE	Sample size	K±SE	HSI±SE	Sample size	K±SE	HSI±SE	Sample size	K±SE	HSI±SE	Sample size
Autumn '72-'77													
112	Female	1.42±0.01	1.30±0.04	57	1.42±0.02	1.52±0.23	53	1.53±0.03	1.21±0.09	174	1.50±0.02	1.13±0.03	41
103	Male	1.43±0.01	1.29±0.05	37	1.43±0.02	1.40±0.05	52	1.61±0.06	1.17±0.09	91	1.57±0.03	1.22±0.05	6
Winter '72-'78													
48	Female	1.39±0.01	1.70±0.09	17	1.51±0.04	1.42±0.17	10	1.54±0.05	1.83±0.08	31	1.61±0.02	1.80±0.09	3
25	Male	1.43±0.03	1.81±0.15	10	1.89±0.49	1.50±0.14	12	1.46±0.03	1.68±0.16	30	1.52±0.02	1.72±0.09	1
Spring '72-'78													
55	Female	1.43±0.02	1.34±0.06	31	1.44±0.03	1.15±0.09	21	2.00±0.15	1.35±0.08	92	1.60±0.02	1.58±0.04	19
44	Male	1.39±0.02	1.31±0.06	22	1.50±0.04	1.10±0.08	49	1.60±0.01	1.20±0.05	41	1.56±0.02	1.16±0.06	0
Summer '72-'78													
8	Female	1.60±0.09	0.95±0.12	4	1.80±0.13	2.30±0.89	75	1.50±0.02	1.23±0.07	40	1.45±0.02	1.30±0.12	8
6	Male	1.58±0.05	0.77±0.09	34	1.48±0.02	0.70±0.04	134	1.49±0.01	0.86±0.06	52	1.42±0.03	0.96±0.09	8
Autumn '78													
0	Female			0			7	2.03±0.49	1.65±0.17	105	1.54±0.01	1.64±0.06	7
0	Male			0			17	1.59±0.02	1.65±0.11	15	1.57±0.04	1.66±0.17	0
Winter '79													
3	Female	1.43±0.04	0.45±0.26	16	1.42±0.03	1.90±0.24	4	1.55±0.09	1.98±0.21	62	1.49±0.02	2.24±0.14	0
5	Male	1.44±0.02	0.97±0.31	19	1.44±0.01	1.89±0.11	20	1.54±0.02	1.83±0.11	16	1.43±0.08	2.01±0.14	1
Spring '79													
0	Female			13	1.47±0.03	0.94±0.07	30	1.53±0.02	1.30±0.07	96	1.60±0.01	1.77±0.05	8
0	Male			4	1.48±0.05	0.83±0.13	30	1.57±0.03	1.22±0.08	36	1.60±0.01	1.32±0.05	1
Summer '79													
0	Female			22	1.57±0.02	1.04±0.08	163	1.58±0.01	1.25±0.03	32	1.56±0.05	1.54±0.09	5
0	Male			27	1.50±0.04	0.82±0.06	49	1.51±0.02	0.73±0.03	7	1.27±0.13	0.56±0.09	1
Autumn '79													
0	Female			0			86	1.50±0.01	1.11±0.04	48	1.49±0.01	1.41±0.06	9
0	Male			2	1.48±0.01	0.88±0.20	44	1.54±0.02	1.05±0.05	13	1.49±0.04	1.10±0.08	0
Winter '80													
0	Female			0			37	1.47±0.01	0.91±0.04	11	1.37±0.05	1.26±0.12	3
0	Male			0			13	1.50±0.02	1.00±0.07	6	1.41±0.02	1.32±0.11	1
Spring '80													
0	Female			8	1.57±0.03	1.02±0.17	47	1.58±0.02	1.35±0.06	31	1.60±0.03	1.78±0.11	12
0	Male			6	1.60±0.03	0.93±0.08	8	1.71±0.03	1.35±0.11	31	1.60±0.02	1.47±0.11	2

TABLE 5. (Continued)  
Seasonal condition coefficient (K[standard length]) and hepatosomatic index (HSI) of *Cynoscion nebulosus* from Mississippi Sound relative to year, sex, and length of fish.

	Standard length in millimeters											
	<140			140-219			220-299			300-399		
	Sample size	K±SE	HSI±SE	Sample size	K±SE	HSI±SE	Sample size	K±SE	HSI±SE	Sample size	K±SE	HSI±SE
Summer '80												
Female	0			1	1.56	0.58	50	1.53±0.03	1.23±0.07	7	1.44±0.08	1.54±0.08
Male	0			10	0.94±0.02	0.58±0.08	21	1.57±0.02	0.83±0.07	3	1.54±0.04	0.94±0.07
Autumn '80												
Female	0			3	2.12±0.44	1.08±0.14	15	1.57±0.02	1.21±0.10	40	1.50±0.02	1.62±0.06
Male	0			4	1.66±0.02	1.15±0.22	62	1.58±0.01	1.21±0.05	17	1.54±0.03	1.54±0.09
										1	1.45	1.43

TABLE 6.

Seasonal condition coefficient (K[standard length]) and hepatosomatic index (HSI) of *Cynoscion nebulosus* from Mississippi Sound from 1972-1980 relative to sex and length of fish.

	Standard length in millimeters											
	<140			140-219			220-299			300-399		
	Sample size	K±SE	HSI±SE	Sample size	K±SE	HSI±SE	Sample size	K±SE	HSI±SE	Sample size	K±SE	HSI±SE
Autumn												
Female	119	1.42±0.01	1.29±0.04	53	1.45±0.03	1.30±0.05	134	1.51±0.01	1.13±0.04	285	1.50±0.01	1.36±0.03
Male	112	1.43±0.01	1.32±0.05	36	1.46±0.02	1.29±0.06	150	1.54±0.01	1.19±0.04	78	1.50±0.02	1.29±0.06
Winter												
Female	51	1.40±0.01	1.63±0.10	33	1.46±0.03	1.65±0.15	51	1.49±0.01	1.17±0.07	105	1.50±0.01	1.93±0.06
Male	30	1.43±0.02	1.67±0.15	29	1.59±0.16	1.76±0.14	45	1.51±0.02	1.56±0.09	52	1.48±0.03	1.77±0.08
Spring												
Female	55	1.42±0.01	1.35±0.06	50	1.47±0.02	1.09±0.06	81	1.56±0.01	1.34±0.04	207	1.60±0.01	1.70±0.03
Male	45	1.40±0.02	1.29±0.06	26	1.50±0.03	1.04±0.07	86	1.60±0.01	1.22±0.04	106	1.58±0.01	1.31±0.04
Summer												
Female	8	1.60±0.09	0.95±0.12	27	1.60±0.03	1.20±0.15	255	1.56±0.01	1.27±0.03	74	1.49±0.02	1.36±0.07
Male	8	1.52±0.06	0.75±0.07	66	1.48±0.01	0.74±0.04	149	1.50±0.01	0.77±0.02	53	1.42±0.02	0.76±0.04
										4	1.26±0.13	0.80±0.21

TABLE 7.  
Bimonthly condition coefficients calculated using total length of *Cynoscion nebulosus*  
from Mississippi Sound and Barataria Bay, Louisiana.

Month	Sex	N	Mississippi Sound			Barataria Bay <sup>1</sup>	
			All fish $K_{TL} \pm SE$	N	> 275 mm SL $K_{TL} \pm SE$	1976 $K_{TL}$	1978 $K_{TL}$
Feb	M	39	0.92±0.01	22	0.94±0.02	0.83	
	F	58	0.91±0.01	40	0.96±0.01	0.85	
Apr	M	131	0.96±0.01	73	1.00±0.01	1.05	0.99
	F	178	0.95±0.01	117	1.01±0.01	1.06	1.02
Jun	M	76	0.92±0.01	30	0.99±0.01	1.00	0.92
	F	166	0.97±0.01	39	1.03±0.02	1.04	0.97
Aug	M	122	0.92±0.01	78	0.92±0.01	1.01	0.89
	F	148	0.96±0.01	88	0.96±0.02	0.98	0.93
Oct	M	120	0.97±0.01	49	0.96±0.01	1.01	0.91
	F	207	0.94±0.01	183	0.93±0.01	1.00	0.87
Dec	M	184	0.84±0.01	33	0.96±0.01	0.95	
	F	272	0.87±0.01	112	0.97±0.01	0.94	

<sup>1</sup> Based on graphs published by Hein and Shepard (1980).

Condition coefficient, gonad weight, and liver weight all varied seasonally and were at least partially related. The contribution of gonad weight to K showed significance only for stage V females limited to spring and summer (Table 15). Patterns in variation among the three factors intensified in fish > 400 mm long. From data presented, the exact relationship is speculative. Relative weight of gonads, especially ovaries, was high in spring and summer, whereas relative liver weight steadily decreased from a high in winter. Hein and Shepard (1979b) reported seasonal variations in K and GSI for samples of spotted seatrout greater than 230 mm TL in Louisiana. Their average values produced a pattern similar to that from Mississippi with differences occurring between male and female counterparts. However, when compared with Mississippi averages, most values for 1976 Louisiana samples were higher and many for 1978 Louisiana samples were lower. Those authors (1979a) also calculated K and GSI values for Louisiana fish over 310 mm TL caught October, November, and December from marsh environments and compared them with corresponding values for fish from sandy coastal areas and islands. The K values for those two groups were similar, but GSI was higher for females in marshes during October and November than in coastal areas during those months. Average total weight for those females, however, was considerably less during those two months suggesting continual recruitment of fish from the marsh into the coastal stock. The commercial Ritchie Fish Computer (Professional Model) established  $K_{TL}$  for the spotted seatrout as 1.0 which is misleading as shown by this study. For some cases, mostly involving freshwater fishes, K values have been known to increase with age, differ according to sex, and change during spawning (e.g., Lagler 1952). Lagler

suggested that for best comparisons, K values should characterize fish of the same length, age, and sex. Comparisons can have merit when using data from similar sites at different times or from different localities at the same time.

All three indices used above provide useful tools for fisheries management; however, they may be misused and the reasons for their relationships are complex. Nutritional and environmental parameters apparently play important roles in addition to those involving maturation and spawning. Data for females and males are usually separated because females grow faster and in later years are more abundant than males (e.g., Tabb 1961).

Two examples illustrate some of the confusion involving the HSI. Bulow et al. (1978) found that the bluegill, *Lepomis macrochirus* Rafinesque, in two lakes in Tennessee had a high HSI in May when the GSI was highest and attributed that HSI to high food intake. The bluegill feeds throughout the year, but growth is most efficient at about 30°C (Lemke 1977). The authors recognized other contributing factors influencing HSI and did not sample from December to March. In the dab, *Limanda limanda* (Linnaeus), from the North Sea, the HSI was high from October to March, reaching a peak at or just preceding early spawning, and the index corresponded directly with K (Htun-Han 1978). Unlike the bluegill, the dab does not feed during winter. Htun-Han (1978) assumed the changes in K related to depletion of body reserves during gonad maturation. He could not relate decrease in liver weight with vitellogenesis as others have done because the HSI remained relatively high and constant throughout the spawning period. He suggested that HSI and K declined because the dab stopped feeding during winter. Contrarily, the plaice, *Pleuronectes platessa* Linnaeus, from

TABLE 8.  
Seasonal condition coefficient (K (standard length)) and hepatosomatic index (HSI) of *Oxyechinus nebulosus* from Mississippi Sound and adjacent areas relative to the fish's stage of maturity.

Sample size	I			II			III			IV			V			VI			VII		
	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size
Autumn '72-77	134	1.43±0.01	1.27±0.04	56	1.43±0.02	1.51±0.24	185	1.66±0.02	1.11±0.03 <sup>1</sup>	53	1.65±0.05	1.32±0.09 <sup>1</sup>	9	1.65±0.10	1.45±0.31 <sup>1</sup>	0		0			0
Female	138	1.43±0.01	1.32±0.04	81	1.44±0.01	1.28±0.06	60	1.76±0.06	1.08±0.07 <sup>1</sup>	8	1.69±0.11	1.36±0.19 <sup>1</sup>	3	1.66±0.05		0		0			0
Winter '72-78	47	1.44±0.02	1.69±0.09	18	1.41±0.03	1.57±0.14	34	1.49±0.02	1.66±0.07	10	1.52±0.05	2.21±0.22	0			0		0			0
Female	28	1.43±0.02	1.73±0.13	17	1.70±0.28	1.57±0.13	53	1.52±0.02	1.75±0.09	0			0			0		0			0
Spring '72-78	68	1.43±0.02	1.33±0.05	22	1.50±0.03	1.11±0.08	11	1.60±0.09	1.42±0.13	32	1.81±0.10	1.40±0.05 <sup>1</sup>	81	1.61±0.02	1.65±0.05 <sup>1</sup>	0		0			0
Female	53	1.40±0.02	1.27±0.06	6	1.52±0.04	0.98±0.13	40	1.54±0.02	1.20±0.07	45	1.60±0.01	1.10±0.05	12	1.67±0.03	1.37±0.08	1	1.56±0.00				0
Summer '72-78	10	1.60±0.07	1.04±0.11 <sup>1</sup>	7	1.44±0.05	0.76±0.09	9	1.53±0.03	0.97±0.18 <sup>1</sup>	24	1.44±0.03	1.23±0.12 <sup>1</sup>	84	1.50±0.02	1.40±0.09 <sup>1</sup>	0		0			0
Female	15	1.49±0.04	0.68±0.07 <sup>1</sup>	66	1.44±0.01	0.67±0.03	67	1.48±0.01	0.89±0.04 <sup>1</sup>	31	1.42±0.03	1.08±0.12 <sup>1</sup>	56	1.51±0.03	1.10±0.14 <sup>1</sup>	0		0			0
Autumn '78	0			2	1.55±0.12	1.65±0.40	107	1.37±0.03	1.63±0.06	8	1.55±0.05	1.88±0.17	2	1.55±0.05	2.64±0.55	0		0			0
Female	24	1.59±0.01	1.35±0.09	24	1.60±0.02	1.76±0.12	6	1.51±0.02	1.34±0.13	0			0			0		0			0
Winter '79	7	1.42±0.06	0.99±0.23	13	1.41±0.03	2.24±0.22	60	1.50±0.02	2.20±0.15	4	1.44±0.04	2.07±0.20	1	1.49	2.04	0		0			0
Female	20	1.44±0.01	1.46±0.17	21	1.42±0.06	2.05±0.16	19	1.55±0.02	1.97±0.09	1	1.55	2.04	0			0		0			0
Spring '79	0			26	1.49±0.02	1.09±0.04 <sup>1</sup>	22	1.54±0.03	1.54±0.09	0			97	1.61±0.01	1.79±0.04	1	1.54	2.24	1	1.43	1.24
Female	0			1	1.36±0.09	0.74±0.00	37	1.58±0.02	1.32±0.06	0			32	1.58±0.03	1.20±0.06	0		0			0
Summer '79	0			38	1.78±0.23	0.88±0.06	6	1.52±0.05	0.98±0.07	5	1.53±0.02	1.08±0.12	168	1.58±0.01	1.40±0.03	0		0			0
Female	9	1.33±0.04	0.72±0.10	5	1.49±0.05	0.81±0.07	5	1.49±0.05	0.81±0.07	6	1.52±0.04	0.71±0.06	63	1.50±0.03	0.74±0.03	0		0			0
Autumn '79	0			21	1.49±0.02	1.21±0.08	109	1.50±0.01	1.26±0.05	0			8	1.48±0.05	1.61±0.13	0		0			0
Female	2	1.70±0.22	1.26±0.27	23	1.57±0.02	1.13±0.07	32	1.50±0.02	0.99±0.06	0			2	1.43±0.04	1.07±0.01	0		0			0
Winter '80	0			0			48	1.44±0.01	0.99±0.05	3	1.43±0.02	2.44±0.19	0			0		0			0
Female	1	1.49	0.77	30	1.55±0.02	1.10±0.06	16	1.52±0.03	1.55±0.14	3	1.51±0.04	1.65±0.26	44	1.88±0.27	1.76±0.09	4	1.84±0.11	1.92±0.35	0		0
Spring '80	0			1	1.47	1.05	27	1.61±0.02	1.34±0.09	6	1.59±0.04	1.98±0.26	13	1.63±0.04	1.17±0.12	0		0			0
Female	0			8	1.51±0.01	0.89±0.08 <sup>1</sup>	4	1.45±0.05	0.74±0.11	0			36	1.54±0.04	1.38±0.08	2	1.37±0.13	1.71±0.04	9	1.49±0.06	1.14±0.10
Summer '80	0			5	1.48±0.04	0.72±0.19	23	1.57±0.02	0.81±0.06 <sup>1</sup>	0			6	1.58±0.02	0.67±0.07	0		0			0
Female	1	1.81	1.21	12	1.63±0.14	1.20±0.15	53	1.53±0.01	1.56±0.06	0			0			0		0			0
Autumn '80	2	1.57±0.06	1.00±0.02	69	1.58±0.01	1.32±0.05	12	1.53±0.04	1.11±0.12	0			1	1.53	0.82	0		0			0
Female																					

<sup>1</sup> Sample size for HSI slightly lower than for K.

TABLE 9.  
Seasonal condition coefficient (K (standard length)) and hepatosomatic index (HSI) of *Oxyechinus nebulosus* from Mississippi Sound between 1972 and 1980 relative to the fish's stage of maturity.

Stage of Maturity																										
I			II			III			IV			V			VI			VII								
Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE	Sample size	K-SE	HSI-SE						
Autumn	134	1.42±0.01	134	1.28±0.04	80	1.49±0.02	80	1.26±0.05	371	1.50±0.01	367	1.32±0.03	33	1.53±0.05	31	1.33±0.09	16	1.51±0.04	13	1.64±0.18	0	0	5	1.55±0.09	5	0.93±0.09
Female	142	1.44±0.01	142	1.32±0.04	155	1.54±0.01	155	1.32±0.04	78	1.48±0.01	78	1.06±0.04	1	1.43	1	1.01	6	1.56±0.06	3	0.99±0.11	0	0	0	0	0	0
Winter	55	1.44±0.02	55	1.58±0.09	31	1.41±0.02	31	1.85±0.14	142	1.49±0.01	142	1.62±0.06	17	1.49±0.03	17	2.22±0.13	1	1.49	1	2.03	0	0	0	0	0	0
Female	48	1.43±0.01	48	1.62±0.11	44	1.54±0.11	44	1.74±0.10	65	1.75±0.01	65	1.66±0.07	2	1.51±0.03	2	1.85±0.27	0	0	0	0	0	0	0	0	0	0
Spring	69	1.42±0.02	69	1.37±0.05	70	1.51±0.01	70	1.08±0.04	43	1.53±0.02	43	1.53±0.08	25	1.54±0.02	24	1.41±0.07	211	1.62±0.01	211	1.73±0.03	5	1.78±0.12	5	1.99±0.31	1	1.24
Male	53	1.40±0.02	53	1.27±0.06	8	1.49±0.03	8	0.96±0.10	95	1.57±0.01	95	1.29±0.04	53	1.60±0.01	53	1.21±0.06	56	1.62±0.02	56	1.24±0.05	0	0	0	0	0	0
Summer	10	1.60±0.07	8	1.04±0.11	52	1.53±0.02	51	0.94±0.05	14	1.48±0.03	14	0.84±0.06	15	1.44±0.03	15	1.20±0.12	266	1.66±0.01	260	1.40±0.03	2	1.71±0.18	2	1.71±0.05	14	1.48±0.04
Female	15	1.49±0.04	14	0.68±0.07	79	1.43±0.01	79	0.69±0.03	83	1.50±0.01	84	0.85±0.04	23	1.42±0.03	19	0.79±0.02	77	1.49±0.02	77	0.75±0.03	0	0	0	0	0	0



TABLE 10.  
Gonosomatic index (GSI) of *Cynoscion nebulosus* relative to length of fish.

	Standard length in millimeters									
	< 140		140-219		220-299		300-399		≥ 400	
	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE
Autumn '72-'77										
Female	112	0.15±0.02	57	0.31±0.04	53	0.69±0.07	174	0.56±0.02	41	0.70±0.04
Male	103	0.02±0.01	37	0.11±0.05	52	0.21±0.02	91	0.25±0.02	6	0.14±0.03
Winter '72-'78										
Female	48	0.05±0.01	17	0.20±0.03	10	0.52±0.11	31	0.74±0.04	3	0.96±0.14
Male	25	0.02±0.01	10	0.12±0.02	12	0.14±0.03	30	0.32±0.03	1	0.16
Spring '72-'78										
Female	55	0.12±0.03	31	0.24±0.03	21	1.34±0.24	92	3.06±0.20	19	5.10±0.84
Male	44	0.06±0.01	22	0.29±0.05	49	1.25±0.06	41	1.19±0.07	0	
Summer '72-'78										
Female	8	0.51±0.05	4	5.45±3.78	75	2.77±0.20	40	3.66±0.24	8	4.01±0.71
Male	6	0.00±0.00	34	0.43±0.07	134	0.82±0.05	52	1.25±0.07	8	1.48±0.35
Autumn '78										
Female	0		0		7	0.68±0.03	105	0.70±0.02	7	0.97±0.08
Male	0		0		17	0.18±0.07	15	0.15±0.01	0	
Winter '79										
Female	3	0.04±0.04	16	0.35±0.06	4	0.72±0.08	62	0.95±0.05	0	
Male	5	0.05±0.02	19	0.06±0.01	20	0.10±0.01	16	0.20±0.03	1	0.16
Spring '79										
Female	0		13	0.40±0.04	30	2.19±0.37	96	3.20±0.23	8	1.77±0.62
Male	0		4	0.90±0.30	30	1.05±0.07	36	1.14±0.06	1	1.24
Summer '79										
Female	0		22	1.20±0.21	163	3.50±0.15	32	4.98±0.24	5	4.29±0.45
Male	0		27	0.82±0.06	49	1.02±0.05	7	1.20±0.08	1	0.90
Autumn '79										
Female	0		0		86	0.62±0.02	48	0.63±0.02	9	1.22±0.17
Male	0		2	0.46±0.14	44	0.18±0.02	13	0.25±0.05	0	
Winter '80										
Female	0		0		37	0.82±0.02	11	0.80±0.03	3	0.93±0.07
Male	0		0		13	0.10±0.01	6	0.15±0.02	1	0.19
Spring '80										
Female	0		8	0.37±0.04	47	1.53±0.20	31	2.57±0.44	12	1.73±0.28
Male	0		6	1.01±0.05	8	1.20±0.11	31	0.93±0.11	2	1.03±0.52
Summer '80										
Female	0		1	0.42	50	2.65±0.26	7	4.59±0.49	1	5.01
Male	0		10	0.37±0.04	21	0.56±0.09	3	0.41±0.15	0	
Autumn '80										
Female	0		3	0.27±0.10	15	0.55±0.03	40	0.65±0.02	8	0.79±0.04
Male	0		4	0.09±0.03	62	0.18±0.03	17	0.14±0.02	1	0.15
Autumn '72-'80										
Female	119	0.16±0.02	53	0.27±0.02	133	0.61±0.03	283	0.64±0.01	46	0.89±0.05
Male	111	0.02±0.01	36	0.14±0.06	150	0.18±0.02	75	0.21±0.02	6	0.13±0.02
Winter '72-'80										
Female	51	0.05±0.01	33	0.28±0.04	51	0.75±0.03	105	0.84±0.02	6	0.94±0.07
Male	30	0.03±0.01	29	0.08±0.01	45	0.11±0.01	52	0.27±0.02	3	0.17±0.01
Spring '72-'80										
Female	55	0.12±0.03	50	0.30±0.02	81	1.79±0.18	207	3.00±0.15	31	4.39±0.49
Male	45	0.07±0.01	26	0.42±0.08	86	1.17±0.05	106	1.12±0.05	3	1.10±0.38
Summer '72-'80										
Female	8	0.05±0.05	27	1.72±0.55	252	3.28±0.12	73	4.43±0.17	10	4.50±0.55
Male	8	0.00±0.00	66	0.56±0.04	148	0.72±0.04	50	1.09±0.06	4	0.96±0.14

TABLE 11.  
Gonosomatic index (GSI) of *Cynoscion nebulosus* relative to the fish's stage of maturity.

	Stage of maturity											
	I		II		III		IV		V		VI	
	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE
Autumn '72-'77												
Female	134	0.15±0.02	56	0.40±0.04	185	0.58±0.02	53	0.70±0.03	9	1.49±0.46	0	0
Male	138	0.02±0.01	81	0.20±0.03	60	0.27±0.02	8	0.55±0.10	0	0	0	0
Winter '72-'78												
Female	47	0.07±0.02	18	0.14±0.03	34	0.64±0.04	10	0.94±0.05	0	0	0	0
Male	28	0.03±0.01	17	0.10±0.02	33	0.32±0.02	0	0	0	0	0	0
Spring '72-'78												
Female	68	0.13±0.02	22	0.33±0.03	11	0.92±0.09	32	1.67±0.16	80	3.98±0.25	0	0
Male	53	0.06±0.01	6	0.38±0.05	40	0.92±0.07	45	1.36±0.07	12	1.30±0.13	0	0
Summer '72-'78												
Female	10	0.34±0.30	7	0.51±0.11	9	0.83±0.20	24	2.73±0.29	84	3.83±0.21	0	0
Male	15	0.04±0.02	66	0.37±0.03	67	0.86±0.04	31	1.32±0.13	56	1.49±0.07	0	0
Autumn '78												
Female	0		2	0.40±0.08	107	0.70±0.01	8	0.84±0.06	2	1.36±0.00	0	0
Male	2	0.04±0.03	24	0.17±0.05	6	0.17±0.02	0	0	0	0	0	0
Winter '79												
Female	7	0.29±0.14	13	0.34±0.05	60	0.93±0.05	4	1.11±0.07	1	1.11	0	0
Male	20	0.05±0.01	21	0.09±0.01	19	0.19±0.03	1	0.13	0	0	0	0
Spring '79												
Female	0		26	0.49±0.03	22	0.91±0.03	0	0	97	3.95±0.21	1	0.72
Male	0		1	0.21±0.00	37	0.94±0.06	0	0	32	1.27±0.05	0	0
Summer '79												
Female	0		38	0.76±0.16	6	1.03±0.35	5	4.07±0.39	168	4.27±0.12	5	1.22±0.32
Male	0		9	0.61±0.12	5	0.76±0.11	6	1.00±0.10	63	1.04±0.04	0	0
Autumn '79												
Female	0		21	0.52±0.02	109	0.64±0.01	0	0	8	1.22±0.19	0	0
Male	2	0.04±0.02	23	0.10±0.01	32	0.26±0.02	0	0	2	0.59±0.01	0	0
Winter '80												
Female	0		0		48	0.81±0.02	3	0.93±0.07	0	0	0	0
Male	0		6	0.10±0.01	13	0.12±0.01	1	0.19	0	0	0	0
Spring '80												
Female	1	0.34	30	0.48±0.04	16	1.01±0.06	3	1.40±0.10	44	2.67±0.22	4	6.20±1.94
Male	0		1	0.13	27	0.80±0.08	6	0.84±0.13	13	1.58±0.13	0	0
Summer '80												
Female	0		8	0.54±0.04	4	0.77±0.08	0	0	36	3.96±0.24	2	4.11±0.58
Male	0		5	0.28±0.07	23	0.38±0.04	0	0	6	1.07±0.14	0	0
Autumn '80												
Female	1	0.15	12	0.46±0.04	53	0.68±0.01	0	0	0	0	0	0
Male	2	0.02±0.00	69	0.14±0.02	12	0.30±0.07	0	0	1	0.75	0	0

TABLE 11. (Continued)  
Gonosomatic index (GSI) of *Cynoscion nebulosus* relative to the fish's stage of maturity.

	Stage of maturity									
	I	II	III	IV	V	VI	VII			
	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE
Autumn '72-'80										
Female	134	0.15±0.02	80	0.42±0.02	368	0.63±0.01	33	0.77±0.03	14	1.46±0.23
Male	141	0.02±0.01	155	0.17±0.02	78	0.26±0.02	1	0.08	3	0.64±0.06
Winter '72-'80										
Female	55	0.09±0.02	31	0.22±0.03	142	0.81±0.02	17	0.98±0.04	1	1.11±0.00
Male	48	0.04±0.01	44	0.09±0.01	65	0.25±0.02	2	0.16±0.04	0	0
Spring '72-'80										
Female	69	0.13±0.02	70	0.45±0.02	43	0.94±0.03	25	1.79±0.18	211	3.66±0.14
Male	53	0.06±0.01	8	0.33±0.05	95	0.90±0.04	53	1.30±0.06	56	1.34±0.05
Summer '72-'80										
Female	10	0.34±0.30	52	0.69±0.12	14	0.86±0.15	15	3.78±0.36	262	4.20±0.10
Male	15	0.04±0.02	79	0.39±0.03	85	0.76±0.04	19	1.15±0.09	77	1.08±0.04

TABLE 12.

Liver weight - fish weight relationships of *Cynoscion nebulosus* from Mississippi Sound (using common logarithmic transformation) by sex of fish and season.

Season	Sex	SL range in mm	N	Log FW = Log a + b (Log LW)			
				Log a	b	95% confidence interval of b	Calculated liver weight for a 410g fish
Winter	Male	92-418	144	1.8703	0.8539	0.8000-0.9079	7.40
Winter	Female	75-460	238	1.8871	0.8527	0.8162-0.8891	7.10
Spring	Male	100-419	264	1.9742	0.8967	0.8642-0.9292	5.15
Spring	Female	92-544	423	1.9367	0.8465	0.8273-0.8656	6.29
Summer	Male	40-412	273	2.2239	0.6430	0.5889-0.6970	4.03
Summer	Female	39-453	358	2.1154	0.6576	0.6171-0.6981	5.71
Autumn	Male	76-465	372	1.9454	0.9218	0.8935-0.9501	5.30
Autumn	Female	82-518	624	1.9703	0.8911	0.8688-0.9134	5.26
Summer	Male <sup>1</sup>	40-377	176	2.2118	0.6191	0.5541-0.6841	4.44
Summer	Male <sup>2</sup>	201-412	96	2.2443	0.6730	0.5608-0.7852	3.53
Summer	Female <sup>1</sup>	39-310	73	2.1042	0.7362	0.6315-0.8409	4.91
Summer	Female <sup>2</sup>	209-453	270	2.1356	0.6234	0.5651-0.6816	5.83

<sup>1</sup> Stages I-III. <sup>2</sup> Stages IV-VI.

TABLE 13.

Gonad weight - fish weight relationships of *Cynoscion nebulosus* from Mississippi Sound (using common logarithmic transformation) by sex of fish and season.

Season	Sex	SL range in mm	N	Log FW = Log a + b (Log GW)				
				Log a	b	95% confidence interval of b	Calculated gonad weight for a 410g fish	r
Winter	Male	92-418	121	2.7111	0.5801	0.5223-0.6379	0.68	0.8767
Winter	Female	75-460	204	2.3390	0.5878	0.5651-0.6104	2.92	0.9636
Spring	Male	100-419	239	2.2905	0.5199	0.4952-0.5446	4.17	0.9375
Spring	Female	92-544	405	2.2320	0.4636	0.4487-0.4785	6.63	0.9501
Summer	Male	40-412	263	2.3161	0.3748	0.3380-0.4116	6.19	0.7787
Summer	Female	39-453	356	2.1850	0.3386	0.3116-0.3657	18.34	0.7947
Autumn	Male	76-465	258	2.6544	0.5334	0.4761-0.5906	0.84	0.7536
Autumn	Female	82-518	576	2.3533	0.6878	0.6729-0.7027	2.38	0.9669
Summer	Male <sup>1</sup>	40-377	166	2.3423	0.3620	0.3140-0.4099	5.59	0.7585
Summer	Male <sup>2</sup>	201-412	96	2.1689	0.6016	0.5368-0.6665	5.47	0.8849
Summer	Female <sup>1</sup>	39-310	70	2.2595	0.4084	0.3373-0.4794	7.33	0.8120
Summer	Female <sup>2</sup>	209-453	271	1.8887	0.5784	0.5326-0.6242	17.86	0.8348

<sup>1</sup> Stages I-III. <sup>2</sup> Stages IV-VI.

TABLE 14.

Seasonal differences in mean weight (in grams) of liver and gonad for *Cynoscion nebulosus* in Mississippi Sound comprising two restricted length-groups in developing III and gravid reproductive stages.

Season	Sex	Stage	N	250-265 mm SL		N	350-365 mm SL	
				Liver wt ± SE	Gonad wt ± SE		Liver wt ± SE	Gonad wt ± SE
Winter	M	III	3	3.81±0.78	0.24±0.04	5	14.51±1.60	1.81±0.39
	F		4	2.13±0.18	1.85±0.19	18	14.98±1.38	5.93±0.28
Spring	M	III	9	4.39±0.36	3.32±0.46	7	9.94±1.87	5.46±1.17
	F		1	6.27	1.88	1	9.95	5.10
Summer	M	III	4	1.84±0.13	1.81±0.31	2	3.81±1.75	4.29±0.44
	F		5	2.44±0.68	2.48±0.64	0		
Autumn	M	III	11	2.54±0.11	0.64±0.21	6	6.92±1.65	1.44±0.22
	F		7	2.61±0.27	1.58±0.15	30	8.87±0.71	4.32±0.25
Winter	M	V	0			3 <sup>1</sup>	10.08±1.81	1.07±0.25
	F		0			8 <sup>1</sup>	13.63±1.40	6.18±0.13
Spring	M	V	2	1.63±0.23	3.41±1.03	7	12.01±1.10	7.05±1.65
	F		10	4.05±0.28	8.08±1.26	22	14.43±0.85	25.41±3.39
Summer	M	V	23	1.87±0.12	3.33±0.19	2	4.20±0.83	4.91±1.09
	F		39	3.38±0.17	10.13±0.76	14	8.55±1.22	30.06±3.22
Autumn	M	V	1	2.20	2.01	0		
	F		3	3.33±0.30	4.34±2.10	1	7.92	5.85

<sup>1</sup> Because no fish 350-365 mm long were collected, these data refer to fish 345-349 mm long.

the Irish Sea did not feed from December until March, but its liver weight was high, especially in lipids, from June to November with a dip in August. Dawson and Grimm (1980) measured the seasonal lipid, glycogen, protein, and ash content in liver and carcass and related the changes in energy

content to ovarian maturation and growth. Although seasonal fluctuations in liver weight and composition were dramatic in the plaice, the amount of energy gained from catabolism during starvation was only about 8% of that from the carcass.

TABLE 15.

Seasonal condition coefficients calculated using standard length and both total weight and that weight minus gonad weight of *Cynoscion nebulosus* from Mississippi Sound.

	Autumn		Winter		Spring		Summer	
	Female	Male	Female	Male	Female	Male	Female	Male
Total sample size	410	79	152	52	279	204	287	184
Sample size	364	75	138	50	43	95	14	84
$K_{(SL)} \pm SE$ Stage III	1.50 $\pm$ 0.01	1.49 $\pm$ 0.01	1.48 $\pm$ 0.01	1.53 $\pm$ 0.01	1.53 $\pm$ 0.02	1.57 $\pm$ 0.01	1.48 $\pm$ 0.03	1.50 $\pm$ 0.01
Sample size	32	1	13	2	25	53	15	23
$K_{(SL)} \pm SE$ Stage IV	1.52 $\pm$ 0.05	1.43 $\pm$ 0.00	1.46 $\pm$ 0.03	1.51 $\pm$ 0.05	1.56 $\pm$ 0.02	1.60 $\pm$ 0.01	1.44 $\pm$ 0.05	1.42 $\pm$ 0.03
Sample size	14	3	1	0	211	56	258	77
$K_{(SL)} \pm SE$ Stage V	1.48 $\pm$ 0.04	1.46 $\pm$ 0.05	1.49 $\pm$ 0.00		1.60 $\pm$ 0.01	1.62 $\pm$ 0.02	1.56 $\pm$ 0.01	1.49 $\pm$ 0.02
Total sample size	410	79	152	52	279	204	283	180
Sample size	364	75	138	50	43	95	14	84
$K_{(SL-G)} \pm SE$ Stage III	1.49 $\pm$ 0.01	1.48 $\pm$ 0.01	1.47 $\pm$ 0.01	1.52 $\pm$ 0.01	1.51 $\pm$ 0.02	1.56 $\pm$ 0.01	1.47 $\pm$ 0.03	1.49 $\pm$ 0.01
Sample size	32	1	13	2	25	53	15	19
$K_{(SL-G)} \pm SE$ Stage IV	1.51 $\pm$ 0.05	1.42 $\pm$ 0.00	1.44 $\pm$ 0.03	1.51 $\pm$ 0.05	1.54 $\pm$ 0.02	1.58 $\pm$ 0.01	1.39 $\pm$ 0.04	1.41 $\pm$ 0.04
Sample size	14	3	1	0	211	56	254	77
$K_{(SL-G)} \pm SE$ Stage V	1.46 $\pm$ 0.04	1.45 $\pm$ 0.05	1.48 $\pm$ 0.00		1.54 $\pm$ 0.01	1.60 $\pm$ 0.02	1.49 $\pm$ 0.01	1.48 $\pm$ 0.02

The seatrout in our study also has a high HSI in winter, but it feeds throughout the year and spawns in summer rather than February-April like the dab. The winter diet in Mississippi may be less in quantity, and, when examined, it did consist more of polychaetes and less of shrimps and fishes than during the rest of the year (Overstreet and Heard 1982), but the quality of the diet probably had little bearing on glycogen intensification in the liver during winter. Heidinger and Crawford (1977) showed experimentally that the HSI of the largemouth bass, *Micropterus salmoides* (Lacépède), in addition to being positively correlated to quantity of daily food intake, increased with a decrease in temperature. These same relationships also held true for percentage glycogen in the liver in that fish. Percentage of crude fat in the liver increased with both an increase in amount of food eaten and in temperature. At least in rainbow trout, HSI and glycogen level increased more when fed a diet high in cerelose (d-glucose) compared to one low in that component, with levels being accelerated at low temperature. When individuals were starved, the two measurements decreased faster than corresponding ones in fish fed a diet low in cerelose, but low temperature reduced this decrease during fasting, potentially jeopardizing the health of fish under those conditions (Hilton 1982). For some species of fish, abundance of glycogen in the liver varied differently at different temperatures depending on amount of exercise (Dean and Goodnight 1964).

In addition to maintaining glycogen in the liver as a storage product, some fish, such as herring, store large amounts of lipids in their flesh whereas others, such as the spotted seatrout, store large amounts in adipose tissue in the body

cavity. During ovarian maturation, visceral lipids are transported to the liver, transformed, and mobilized into development of ova (Sargent 1976). In females, the transfer to the ovary apparently responds to estrogens, whereas in males, mobilization of lipids from adipose depots to muscle and testes is probably controlled by adrenocorticosteroids or prolactin (Dindo and MacGregor 1981). Some difference between mechanisms in females and males is suggested by differences in indices and the abundance of fatty deposition in the liver of females. Lipid abundance was not measured; however, Thompson (1966) analyzed total oil, moisture, protein, and ash of *Cynoscion nothus* (Holbrook) from the northern Gulf of Mexico. The monthly samples composed fish that ranged from 148 to 312 mm TL and averaged 5 to 7% oil and 73 to 75% moisture from 12 August to December and 2 to 4% and 74 to 79%, respectively, from January to 1 August. These reasonably low percentages of oil contrasted with a high of 17% in the related *Leiostomus xanthurus* Lacépède during May (compared to 1% in January). Also, the length of seatrout was relatively small in Thompson's samples, and several fish were probably not mature. In any event, the types of lipid present have a significant relation to energy and condition, and they vary according to temperature and diet (Cowey and Sargent 1972). As an example of effect on K, when levels of high energy triglyceride fats are low, protein rather than lipids may contribute heavily to supplying metabolic energy during catabolism. Since protein is low in energy relative to fats, K values may be low, and using lipid-moisture values as an indication of condition may be prone to gross errors (Caulton and Bursell 1977).



In any event, the liver of the seatrout increases in wet weight during winter similarly to that in the largemouth bass and some other fishes, and it decreases during summer at or following its spawning period the same as in many other fishes. Because reproductive and other cycles differ among fishes, because environmental influences and behavioral patterns differ among most other similarly studied fishes, and because a variety of factors affect the size and composition of the liver, lipid metabolism and transport, and maturation, the seasonal dynamics of the seatrout's liver from Mississippi differ from those in many species, and fluctuations may differ yearly. Moreover, the sensitivity of the HSI is greater than that of  $K$ , as indicated by the higher corresponding SE's in seasonal values.

#### *Size of Mature Fish, Sex Ratio, and Spawning Fish*

Length of fish as well as season influence maturity, and Table 16 presents the differences in fish length relative to season, stage, and sex. Most spawning occurred in summer when 76% of the females and 28% of the males were recorded as gravid or spawning. Nevertheless, in spring these percentages were 51 and 20%, compared to 3 and 2% in autumn, and less than 1% in winter. During summer, about one-quarter of both males and females in the 140 to 219 mm group were gravid (Table 16). These included females 189 and 200 mm SL and seven males 201 to 206 mm. With progressive increase in length-groups of females during summer, the percentage of gravid or spawning individuals was 0, 26, 78, 91, and 100%, suggesting an especially great spawning potential for fish over 220 mm. Also involved in this potential is fecundity, which will be discussed later.

As length of fish increased, the percentage of females present increased (Table 17). Of those examined fish over 400 mm long, few were males. For those less than 300 mm, the number of males and females was about equal. On the other hand, in all length-groups a trend existed for the percentage of females to increase with an increased stage of maturity. Large males, however, occasionally appeared to be abundant. Data on sexed seatrout collected in summer and autumn of 1982 from the same area, but after tabularization of the preceding data and therefore not discussed elsewhere, contained 9, 4, 8, and 0 males in groupings 300 to 349, 350 to 399, 400 to 499, and  $\geq 500$  mm SL, respectively, compared to 13, 3, 5, and 4 females in the same groups. During that 1982 period, the two largest males, a 474 mm SL gravid one and a 463 mm SL postspawning one, weighed 1,752 and 1,370 g and had  $K = 1.65$  and 1.38 compared to the largest female which measured 543 mm and weighed 2,540 g with  $K = 1.59$  in December.

The numerous collections of spotted seatrout included 106 lots with nine or more fish. When percentage of females in those samples was considered by length of fish and season of capture and then compared with values for the combined data in Table 16, some trends became apparent. During winter, some groups had more males or females than ex-

pected based on average values in Table 16, but no collections were dominated by a single sex of fish. In spring, a group of 15 fish from Chandealeur Islands consisted of all females. Three nearshore groups (with 10 to 46 fish) from Mississippi Sound were composed of 20, 22, and 90% females, values conspicuously different from the average. These groups, however, were the only conspicuous single-sex-dominated groups from the 25 spring collections having several fish. All these groups contained gravid females. During summer, 15 of 26 collections were sexually disproportionate, and in all those that had at least one female present, at least one female was gravid. Four groups collected from off the barrier islands had 0 to 27% females ( $N = 10$  to 49), each with at least one gravid female, if females were present. Four inshore groups had 7 to 22% females ( $N = 9$  to 76), and seven had 90 to 100% ( $N = 10$  to 49), mostly gravid individuals between 200 to 300 mm long. In other words, a tendency for schooling by sex existed during spawning season. By autumn when 37 groups were examined, three groups from Gautier had 12, 14, and 19% females ( $N = 14$  to 37), and one group of 30 fish from Back Bay of Biloxi contained all females. Other groups had a male:female ratio which was consistent with averages shown in Table 16.

Spawning fish were collected from nearshore habitats at Deer Island (13 May 1980), Pass Christian (24 August 1980), and Davis Bayou (12 August 1980) and from near barrier islands at the south side of Horn Island (8 May 1980) and southwestern Cat Island (21 May 1980). Water temperature ranged between 25 and 30°C and salinity was usually relatively high, but was as low as 10.0 ppt at Deer Island on 13 May. Spent and gravid females also occurred together at the barrier islands (Ship and Cat islands) and at inshore sites (Deer Island and mouth of West Pascagoula River) from June through October. Those schools also contained gravid males and females with developing ovaries. Of those seatrout examined from Galveston Bay, Texas, a group from 28 April 1977 contained spawning females and a group on 8 September 1976 had spent and gravid females.

Spawning is a prolonged process that usually takes place from April to September with some noted cases of spawning individuals occurring as early as March and as late as November. Hein and Shepard (1979b) provided a table that lists spawning data from numerous cited studies conducted from Georgia to Texas. Some of those cited authors suggest two peaks of spawning activity. All the habitats where spawning occurred and where spent and gravid individuals occurred together in Mississippi were shallow. Those off the barrier islands were in or near grass-beds, but those inshore were not. Tabb (1966) and others suggested that the fish prefer deeper areas in estuaries. What happened to embryos and larvae in 10 ppt is uncertain. Arnold et al. (1976) found no adverse effects at 25 to 30 ppt, and Colura (1974) induced spawning in captive fish and followed development of resulting larvae in 14 to 18 ppt. Rapid metamorphosis and growth occurred experimentally at 28°C, but not at all at 23.5°C in Texas

TABLE 16.

Relationship between length and stage of maturity for 2,736 individuals of *Cynoscion nebulosus* from Mississippi Sound separated into males and females on a seasonal basis.

Stage of Development	Standard length in millimeters												Grand Total	
	<140			140-219		220-299		300-399		>400		Total		
	U	M	F	M	F	M	F	M	F	M	F	M		F
Winter														
I	15	23	39	20	9	--	--	--	--	--	--	43	48	91
II		2	9	9	19	28	1	6	--	1	--	46	29	75
III		--	--	--	1	16	49	47	91	1	--	64	141	205
IV		--	--	--	--	--	--	1	11	1	6	2	17	19
V		--	--	--	--	--	--	--	1	--	--	0	1	1
VI		--	--	--	--	--	--	--	--	--	--	0	0	0
VII		--	--	--	--	--	--	--	--	--	--	0	0	0
Total	15	25	48	29	29	44	50	54	103	3	6	155	236	391
Spring														
I	9	44	54	9	15	--	--	--	--	--	--	53	69	122
II		1	5	7	31	--	34	1	1	--	--	9	71	80
III		--	--	9	--	40	6	48	36	1	2	98	44	142
IV		--	--	--	--	32	11	22	19	--	2	54	32	86
V		--	--	2	--	12	38	37	153	2	27	53	218	271
VI		--	--	--	--	--	1	--	4	--	--	0	5	5
VII		--	--	--	--	--	1	--	--	--	--	0	1	1
Total	9	45	59	27	46	84	91	108	213	3	31	267	440	707
Summer														
I	34	9	8	4	1	2	1	--	--	--	--	15	10	25
II		--	--	29	18	49	30	1	--	--	--	79	48	127
III		--	--	16	1	42	8	28	2	--	--	86	11	97
IV		--	--	2	--	8	18	10	5	3	--	23	23	46
V		--	--	16	7	48	188	15	68	1	11	80	274	354
VI		--	--	--	--	--	1	--	2	--	--	0	3	3
VII		--	--	--	--	--	13	--	1	--	--	0	14	14
Total	34	9	8	67	27	149	259	54	78	4	11	283	383	666
Autumn														
I	10	109	106	26	27	6	--	1	--	--	--	142	133	275
II		3	13	8	25	109	32	23	6	2	1	145	77	222
III		--	--	1	--	34	94	39	228	4	16	78	338	416
IV		--	--	--	--	1	1	--	9	--	23	1	33	34
V		--	--	1	--	1	2	4	4	--	8	6	14	20
VI		--	--	--	--	--	--	--	--	--	--	0	0	0
VII		--	--	--	--	--	4	--	1	--	--	0	5	5
Total	10	112	119	36	52	151	133	67	248	6	48	372	600	972

U = Unsexed immature individuals.

(Colura 1974). In addition to the studies in the southeastern United States, Tucker and Brown (1981) reported peaks in natural spawning, 18 May - 14 June and 13-26 July, in the spotted seatrout from the Chesapeake Bay of Virginia where requirements may differ. In summary, the period for spawning varies somewhat geographically and yearly, often with two apparent peaks, one about May-June and one in July-August. In Mississippi during most years, some individuals spawn monthly from May through August and rarely into October.

The appearance of fish 10 mm SL or less throughout Mississippi Sound, adjacent bays, and Gulf of Mexico immediately adjacent to the barrier islands reflect recent

spawning. These fish have been collected by GCRL personnel in small numbers, but even fish 3.0 mm SL occur within all general areas (Loman 1978, Sally Richardson and Joanne Laroche, personal communication, James Warren, personal communication). Specimens 2.5 mm SL have been collected as early as 6 May and as late as 12 September (Richardson and Laroche, personal communication). Over 70% of fish shorter than 50 mm SL in Mississippi come from shallow areas with grassy bottoms (Loman 1978). Year-old fish 130 to 155 mm SL occur concurrently in May and growth can be approximated using monthly length-frequency diagrams (James Warren, personal communication).

Some seatrout spawn at a small size. Determining age by

TABLE 17.

Percentage of female *Cynoscion nebulosus* by length-group (sample-size in parentheses). Data for localities other than Mississippi are derived from small samples collected in spring, summer, and autumn, except for the lack of an autumn sample from Florida.

	Standard length in millimeters					Total
	<140	140-219	220-299	300-399	>400	
Mississippi Sound, Mississippi <sup>1</sup>	55.0 (425)	49.2 (313)	55.4 (961)	69.4 (925)	85.7 (112)	60.6 (2736)
Chandeleur Islands, Louisiana	--	41.6 (12)	53.2 (92)	57.5 (66)	100.0 (5)	55.4 (175)
Galveston Bay, Texas	--	--	6.2 (16)	41.8 (43)	73.3 (15)	40.5 (74)
Apalachee and Tampa bays, Florida	--	--	44.1 (34)	85.7 (42)	100.0 (3)	60.6 (89)

<sup>1</sup> Note discussion in text on additional collections in 1982 containing a high percentage of large males.

scales and otoliths sometimes provides questionable results, although at least some individuals spawn in their second year and most do in the third year. Workers from Florida, Louisiana, and Texas have found gravid females nearly as short as some of those occurring in this study as well as gravid males shorter than in this study (Klima and Tabb 1959, Stewart 1961, Hein and Shepard 1979b, Miles 1951).

The fact that seatrout can spawn when less than 20 cm long does not have nearly the influence on the fishery as the facts that 1) percentage of gravid females increases with body length and 2) larger females produce more eggs than smaller ones. These factors will be discussed below. The jump from less than 30% of the females being gravid or spawning when less than 30 cm long to over 90% when greater than 30 cm becomes considerably important when one recognizes the increased percentage of females in the subpopulation related with increase in length of fish. Male: female ratios in Georgia, Louisiana, and Texas have been reported as 1:1.7, 1:2.4, and 1:2 (Mahood 1975, Hein and Shepard 1979b, Pearson 1929), but unless fish are divided into length-groups, such ratios can be misleading and even then relatively large sample sizes are necessary. Unlike samples from Mississippi, those grouped by age from east-central Florida and by length from northwestern Florida contained no male fish above 7 years old and 375 mm SL long, respectively (Tabb 1961, Klima and Tabb 1959).

Data from Texas, Florida, and Chandeleur Islands (Table 17) exemplify some problems created by small samples. In Chandeleur collections during summer, 30 stage V fish 220 to 299 mm long were males compared to 9 females. In autumn when fish were not gravid, there were 28 males and 4 females 220 to 399 mm long in stage II compared to 4 males and 46 females in stages III and IV. The same pattern held in Texas samples except the autumn break favoring females was at stage IV rather than III. Part of this difference is based on the assumption that females are larger than males of the same age (e.g., Tabb 1961). Based on numerous observations of specific samples in Mississippi, some indicated above, those observations on fish from the three non-Mississippi locations cited above do not represent the entire subpopulations at those locations. Even if they did, samples

taken at other times of the year would alter overall values. Based on the larger samples from Mississippi, one can assume that some large males exist in Florida. Nevertheless, many fishermen recognize the preponderance of large females and call all large trout "sows." Tabb (1966) stated that the schooling behavior of the spotted seatrout in Florida breaks down by age 5 or 6 (2.7 to 3.6 kg) when most males have died, and the "sow," or "gator," trout adopt a semi-solitary existence. Tabb (1961) found 81% of 21-year-old fish from Indian River, (east-central) Florida, were males. First year fish (<140 mm) from Mississippi agree more with those from the Everglades National Park, Florida (Stewart 1961) and during summer, females apparently outnumbered males nearly two to one. Perhaps most fish of undetermined sex were males which would make that ratio about even and contribute to an abundance of males during the summer.

The apparent disproportionate loss of male spotted seatrout with age has not been observed for all seatrouts. Wilk (1980) reported for *C. regalis* an equal sex ratio for all sizes of fish throughout its range along the Atlantic coast. He stated that no differences in sex ratio of fish occurred among years and that no apparent schooling by sex occurred during any time of their life. No literature reference reports schooling by a disproportionate percentage of male and female spotted seatrout as suggested by the several discussed collections from Mississippi.

#### Fecundity and Gonads

Based on calculated numbers of oocytes from ovaries in females for each stage throughout the year, a progressive increase in the number occurred from stage II to IV, but the number per gram of ovary remained approximately equal (Table 18). As can be seen from the corresponding SE's in Table 18, considerable fluctuation existed within each group. Since values for oocyte number in the comparative stages during 1979 and 1980 did not differ substantially, those data were combined. The highest number of oocytes larger than 30  $\mu$ m in diameter from an individual based on the displacement technique was calculated as 10,599,376 and came from a 518 mm gravid female. Using the gravimetric technique, the same fish would have 15,567,833 oocytes.

TABLE 18.

Average fecundity of *Cynoscion nebulosus* from Mississippi Sound in 1979–1980 determined by volumetric displacement method in relation to stage of development.

Stage	N	Calculated mean no. eggs $\pm$ SE	Mean wt of fish in g $\pm$ SE	Mean no. eggs/g fish $\pm$ SE	Mean ovarian wt in g $\pm$ SE	Mean no. eggs/g ovary $\pm$ SE
Maturing virgin	7	1,369,662 $\pm$ 211,048	300.1 $\pm$ 40.5	5,006 $\pm$ 1,274	1.65 $\pm$ 0.29	876,898 $\pm$ 128,127
Developing III	35	2,882,176 $\pm$ 310,051	536.0 $\pm$ 35.8	5,186 $\pm$ 275	4.24 $\pm$ 0.36	663,986 $\pm$ 24,527
Developing IV	6	6,750,669 $\pm$ 538,584	966.6 $\pm$ 85.1	7,340 $\pm$ 976	11.40 $\pm$ 1.63	641,649 $\pm$ 95,055
Gravid	35	2,333,217 $\pm$ 405,887	540.1 $\pm$ 75.3	4,283 $\pm$ 354	15.21 $\pm$ 1.97	175,242 $\pm$ 24,570
Spawning	3	4,051,107 $\pm$ 185,560	634.3 $\pm$ 51.7	6,493 $\pm$ 687	49.14 $\pm$ 14.80	110,558 $\pm$ 46,699
Spent	7	1,806,220 $\pm$ 417,205	371.1 $\pm$ 72.2	5,139 $\pm$ 966	5.07 $\pm$ 1.46	464,756 $\pm$ 89,177

This amount was probably not an atypically large one or was not totally dependent on fish-length because a 402 mm long stage III female had 10,231,237 oocytes (13,044,827 using gravimetric calculations). Moreover, only relatively large oocytes in the aliquots are counted. Figure 3 illustrates length versus percentage-frequency for the different stages and shows no oocytes smaller than 31  $\mu$ m in diameter. Some oocytes about 30 to 50  $\mu$ m and all smaller ones were missed in the aliquots as can be seen from later micrographs of ovarian tissue. The graphs represent gonads sampled throughout the year even though large oocytes were restricted to prespawning, spawning, and postspawning periods.

The number of oocytes per gram of ovary dropped off conspicuously by the time fish became gravid to spent (stages V, VI, and VII) because the eggs were larger. The size of ovaries, however, increased considerably when fish were spawning (Tables 18–19). The mean number of oocytes per gram of fish varied widely, but the number for stages other than V was typically between 5,000 and 7,000. To assess the effects of spawning, the values calculated for number of oocytes in gravid fish were divided into monthly groups (Table 19). The considerable variation in oocytes per gram of ovary during most months plus the relatively low means in May and July illustrate the long spawning period and possibility of two or more spawning peaks, at least for specific individuals. Fish identified as being spent, even though having relatively small numbers of countable oocytes, had an average or nearly average number per gram of fish or per gram of ovary. Many of these were small oocytes (Figure 3).

A few authors have reported the fecundity of a limited number of spotted seatrout (Pearson 1929, Moody 1950, Tabb 1961, Sundararaj and Suttkus 1962, Adkins et al. 1979). Tabb (1961) and Sundararaj and Suttkus (1962) both showed a progression in the number of eggs with length of fish, reaching maximum estimated numbers of about 1,100,000 oocytes both in 625 mm SL (5-to 8-year-old) females in Indian River, Florida, and in 504 mm TL (4-year-old) females in Louisiana. These and the other cited authors counted only large yolkly eggs, presumably near or during spawning periods. Data provided here treat oocytes from 31

to 593  $\mu$ m in diameter rather than those only over 300  $\mu$ m or some other unstated value. On the other hand, a 326 mm

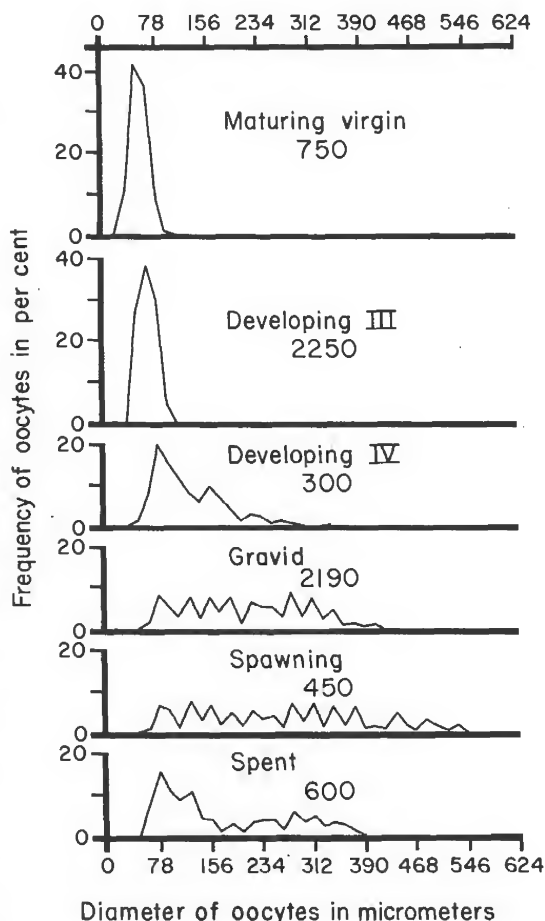


Figure 3. Length-frequency of oocytes over 30  $\mu$ m from *Cynoscion nebulosus* according to stage of maturity.

TABLE 19.

Average monthly fecundity in gravid *Cynoscion nebulosus* from Mississippi Sound in 1979–1980.

Stage	N	Calculated mean no. eggs $\pm$ SE	Mean wt of fish in g $\pm$ SE	Mean no. eggs/g fish $\pm$ SE	Mean ovarian wt in g $\pm$ SE	Mean no. eggs/g ovary $\pm$ SE
March	4	3,695,539 $\pm$ 1,770,561	674.8 $\pm$ 27.4	5,218 $\pm$ 2,390	13.07 $\pm$ 1.30	254,619 $\pm$ 105,469
April	4	4,715,872 $\pm$ 1,397,829	1,048.6 $\pm$ 424.2	4,961 $\pm$ 410	19.99 $\pm$ 10.80	325,043 $\pm$ 65,590
May	7	1,427,752 $\pm$ 212,318	606.5 $\pm$ 49.2	2,404 $\pm$ 418	18.41 $\pm$ 2.91	81,732 $\pm$ 11,071
June	8	1,142,781 $\pm$ 168,044	262.1 $\pm$ 16.6	4,334 $\pm$ 615	6.43 $\pm$ 0.88	219,743 $\pm$ 67,962
July	6	1,039,433 $\pm$ 171,241	246.8 $\pm$ 23.7	4,258 $\pm$ 635	10.61 $\pm$ 1.59	97,856 $\pm$ 7,982
August	4	2,094,323 $\pm$ 503,073	392.8 $\pm$ 89.1	5,307 $\pm$ 282	22.26 $\pm$ 8.33	124,640 $\pm$ 42,275
September	1	3,677,195	672.0	5,457	25.92	141,481

spawning fish in May contained 2,254,134 oocytes over 300  $\mu$ m in diameter (3,968,050 when using gravimetric technique), and several fish had over 1,500,000 large oocytes. Because spawning occurs over several months and because vitellogenesis can proceed rapidly in small oocytes, all oocytes over 30  $\mu$ m should be treated. In fact, one should determine whether oocytes less than 30  $\mu$ m in May also can ripen by August.

Even disregarding problems concerning oocyte-size, estimated fecundity values are not exact. Sundararaj and Suttikus (1962) found they estimated the number of large yolky eggs as 8.5 to 8.9% higher when dealing with 232,936 and 480,180 eggs. Most estimates, such as the one by those authors, have been based on a gravimetric ratio. The displacement ratio appears more accurate to me and is less influenced by the presence of tunica albuginea and "excess" fluid in ovarian tissues. When dividing the estimates of fecundity in Mississippi seatrout using weight by those derived using displacement of water, those using weight had a mean 1.70 $\pm$ 0.03 times greater with a range of from 0.97 to 2.81. Relatively wide variation occurred among values within groups of all the different stages.

Variation in oocyte-count can be attributed to errors in measurements as well as to content of fluid and presence of somatic tissue. Considering the large size of some gravid ovaries, the error in measuring an aliquot (initially totalling about 0.060 $\pm$ 0.002g and 0.10 $\pm$ 0.01 ml) can be significant, especially since it is greatly magnified in the total estimation. Both size and position of aliquot have some influence on accuracy of the method. By doubling the size of the aliquot, the total estimate was occasionally off by a little more than 10%, and when the aliquot was taken from the center of the ovary where no capsular tunic material was present but some oocytes were larger, the estimate was 5 to 8% lower. To these factors, the size of oocytes and the amount of fluid blotted also influence accuracy. In the ovaries of two gravid fish during May, 150 oocytes from their central portions averaged 405 and 357  $\mu$ m in diameter compared to 360 and 332  $\mu$ m for 150 oocytes near the corresponding periphery.

Considering all the factors that result in errors when

determining fecundity, the numbers listed in Tables 18 and 19 may be somewhat low. In any event, they are not unrealistic and suggest that the spotted seatrout is capable of spawning many more eggs per season than previously assumed. Even small individuals less than 1 kg maintained under artificial light and temperature regimes spawn several million eggs per year (Colura, personal communication). The modes and medians of ripe egg diameters, between 440 and 500  $\mu$ m, showed the same differences. Colura (1974), when artificially inducing spawning in the seatrout using human chorionic gonadotropin (HCG), found that ovulation always occurred when ovarian eggs were initially at least 462  $\mu$ m in diameter and never when less than 410  $\mu$ m. Data in Figure 3 support those findings; only spawning fish had oocytes larger than 406  $\mu$ m. Fable et al. (1978) reported that spawned eggs measured 0.73 to 0.82 mm in diameter, averaging 0.77 mm and ranging from 0.70 to 0.85 mm when preserved.

#### Histology of gonads

In addition to being followed seasonally by gross observations, gonadal development was concurrently studied by histological observations of representative samples. Diagnoses from sections occasionally did not correspond with those gross ones determined from Table 1. Since examination of sectioned material aids in understanding the reproductive biology of the spotted seatrout, some observations occur below.

During late autumn and throughout winter, ovaries of females designated grossly as stages III and IV typically contained early stage oocytes before vitellogenesis ensued (Figures 4–8). These were seasons when the tunica albuginea surrounding most ovaries reached its maximal thickness. Some oogonia and primary oocytes (e.g., Figure 5) occurred in the ovaries throughout the year. As lipogenesis progressed in more developed oocytes, the presence of yolk vesicles resulted in less basophilic-appearing ooplasm. This less basophilic-appearing (Harris's hematoxylin and eosin Y) ooplasm ultimately took on a reddish color throughout when stained using Masson's trichrome method. The bluish



ooplasm of earlier phases using that method progressively changed from spotted to variegated with the red staining material as the basophilia decreased in intensity. In many ovaries during winter and early spring, the ooplasm developed a zonation with those zones located both peripherally and adjacent to the nucleus being stained darker than the zone in between (Figure 9). Following this yolk-vesicle stage, oocytes in the yolk-globule stage began showing up concurrently with others in the yolk-vesicle stage about April in many fish, and they typically lasted throughout the summer. The reddish-purple-staining (hematoxylin and eosin) vitelline material in the yolk globules occurred both as minute granules in vesicles and as large globules, with the size of the structures depending on the degree of coalescence (Figures 10–13). The globules stained purple with hematoxylin and pink with eosin. Oocytes as small as 70 to 80  $\mu\text{m}$  underwent obvious vitellogenesis as determined by stained globules, but those exhibiting vitellogenesis generally measured 120  $\mu\text{m}$  or larger. Nevertheless, some were smaller than their counterparts in the yolk-vesicle stage. Development of this yolk-globule stage within an individual fish, as well as that of the preceding yolk-vesicle stage, seldom appeared to proceed synchronously. Toward the end of summer, however, most oocytes not in an early oocyte stage had reached the late yolk-globule stage. As the oocytes approached maturation, most yolk globules coalesced into rather large spheres before fusing together, and the yolk vesicles gradually coalesced until a single lipid globule existed (Figures 14–17). Usually no longer spherical at this time, the large oocytes measured up to 560  $\mu\text{m}$  long (Figure 17). As the globules and vesicles coalesced into homogeneous bodies, the nucleus appeared to migrate peripherally and lose its membrane. The oocytes took up fluid before ovulation.

If hydrated ova were not spawned, as commonly occurred in September and October, the overripe bodies, either those shed into the lumen (Figures 18–20) or those retained in the lamellae (Figures 21–22), remained hyaline in appearance. These oocytes degenerated and presumably most of their material was absorbed (Figures 22–24). Because some of the post-spawning females contained such large numbers of these hardened, residual oocytes, they were misdiagnosed as gravid using Table 1.

After fractional release of normal ripe ova, the retained secondary membranes of the oocytes could be recognized as spent and fluid-filled, collapsed or compressed follicles, or as degenerating follicles (Figures 17, 24–26). As seen in some previous figures, not all oocytes ripened or ovulated simultaneously. Some relatively well-developed oocytes among many early-stage oocytes that occurred in ovaries during late summer probably never would have spawned had the fish not been sampled (Figures 27–28). In similar cases during June and July, however, such oocytes probably would have continued to mature and be spawned (Figure 29).

Atresia, the regressive absorption of aborted oocytes, involved oocytes in all stages of development. In addition to that fate for the eosinophilic, hyaline, overripe, post-spawning oocytes (e.g., Figure 21), some oocytes in all stages underwent atresia throughout the year. Figure 30 shows one in a premature yolk-vesicle stage. The process can be followed easily, especially in well-developed oocytes because of their yolk components (Figures 31–37).

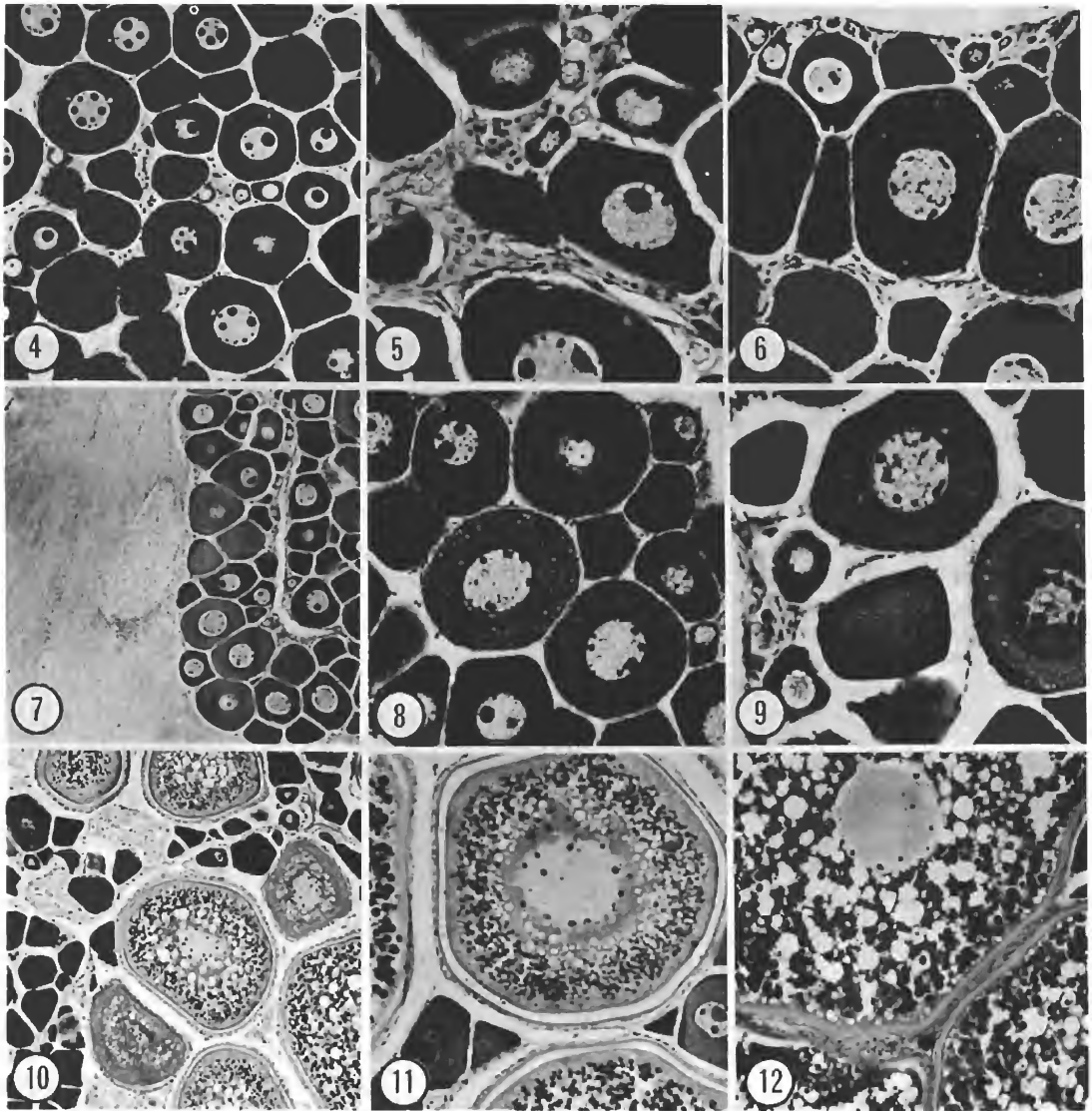
Examination of oocytes both microscopically and histologically showed that no oocytes in prespawning condition occurred in March and few occurred in April. Most ovaries of fish from May through August diagnosed using Table 1 as stages V–VII and many as stages III and IV contained an abundance of oocytes in advanced vitellogenic stages. All those 189 to 217 mm females diagnosed as stage V in summer (Table 16) had secondary or tertiary yolk-globule stage oocytes (see Nash and Shehadeh 1980 or other references for terminology of stages). During May through August, lamellae frequently contained oogonia, primary oocytes, yolk-vesicle oocytes, yolk-globule oocytes, and spent follicles at the same time. In September, stage V-diagnosed fish usually had oocytes in the primary or secondary, but not tertiary, yolk-globule stage. By October, if deposited yolk globules could be seen, they were restricted to oocytes in the primary stage. After that period, any oocytes containing yolk globules exhibited atresia.

The above observations suggest a fractional spawning with a prolonged, or serial, noncontinuous release of ova from May through August. Either a portion of the individuals did not initiate that spawning until June or July or they underwent a resting period at that time without active vitellogenesis transpiring (e.g., Figure 29).

Of all the ovaries examined, only one appeared grossly abnormal. When palpated, a portion felt brittle, much more so than ovaries containing residual hyaline-appearing oocytes. When sectioned, the ovary of this stage III fish in October exhibited a large region of degeneration (Figures 38–39).

In most cases, both developing or mature ovaries appeared similar in size and contained the same developmental stages. Comparative sections from anterior, midregion, and posterior of representative pairs showed little difference along the length or throughout the cross-section.

Numerical designations have been used to classify oocytes into different developmental stages, but because those stages designated by different authors (e.g., Combs 1969, Nash and Shehadeh 1980, Bruslé 1980) do not correspond, I chose to use descriptive names and avoid confusion. As shown from histological evidence from some females and to be supported further with data from males, neither numerical nor descriptive maturation stages for fish always compare with the actual reproductive stage of that individual. Because gonads of all fish were not sectioned and because numerical assignments are useful for comparisons with gross data in other works, they are utilized.



Figures 4–12. Sectioned ovarian tissue from *Cynoscion nebulosus*. 4. "Resting stage" oocytes, most having large spherical nucleoli dispersed throughout their nuclei. Although strongly basophilic, the cytoplasm of oocytes (ooplasm) in this developing III fish in January exhibits a few irregularly-dispersed yolk vesicles. Oogonia and primary oocytes are dispersed among the larger resting stages. 5. Close-up of ovary in developing III fish during November showing oogonia and primary oocytes among resting oocytes. The central small cells with dense nuclei are red blood cells. 6. Primary oocytes, including a small cluster of "chromatin nucleolus stage" oocytes lining the lamellar margin of an ovary in developing III fish during November. The more mature "resting oocytes" contain small basophilic thread-like nucleoli in addition to larger nucleoli (not shown in figure). 7. A developing IV fish in November with typical oocytes of stage III to IV fish from September through November. No large, vitellogenic oocytes occur in these ovaries as they do in post-spawning stage V fish during this same period, but the presumed pallial substance of Balbiani's vitelline body surrounding the nucleus apparently prepares oocytes for vitellogenesis. Note portion of a moderately thick, muscular, intra-lamellar septum arising from the tunica albuginea located in the bottom of the figure. Nerves, such as the one shown, are common in the tunica albuginea. 8. "Post-peri-nucleolus stage" oocytes in developing IV fish during February with smaller nucleoli peripherally located. Lipogenesis actively resulting in small yolk and lipid vesicles in ooplasm of some oocytes and thereby producing a decrease in basophilic-appearing ooplasm. 9. Oocytes from a developing III fish in April stained using Masson's trichrome method showing

Spermatogenesis, as well as oogenesis, progressed seasonally. Developmental components within an individual usually appeared similar throughout both testes, except in immature fish. In those, developmentally active cells occurred less abundantly in the anterior and central portions of a testis. In late autumn and early winter, the testes of fish diagnosed as stage I did not exhibit active spermatocytogenesis (Figure 40), but those in more advanced stages revealed various degrees of activity. Figure 40 illustrates the branching network of tubules in this unrestricted continuous spermatogonial testis-type as defined by Grier (1981). Figures 41 and 42 illustrate early development. Some testes had more advanced phases, and by spring active spermatogenesis had proceeded extensively in compact tubules. Relatively few spermatozoa, however, were being produced (Figure 43). By May, many males had gravid testes (Figure 44). Most testes remained with spermatozoa packed in tubule lumens until about September when the testes appeared to reach their spent condition, even though residual spermatozoa remained in the lumens for several months (Figures 45–46). As indicated earlier, a few testes actively produced some spermatozoa during autumn and winter months.

The processes of spermatocytogenesis (the first stage in which spermatogonia develop into spermatocytes which in turn produce spermatids) and spermiogenesis (the second stage in which spermatids transform into spermatozoa) together constitute spermatogenesis and take place within germinal cysts surrounded at this stage by compressed Sertoli cells and bound together by a basement membrane and boundary cells. Leydig cells can be seen along the basement membrane. Development occurs almost synchronously within each cyst. Figures 47 and 48 show several of these cysts in March and May, respectively, and Figures 49 through 57 magnify the various stages. Free spermatozoa occurred in most testes after April. They even occurred in lumens of tubules of fish diagnosed as virgin (Figure 58). By September, most residual spermatozoa in mature and developing fish were restricted to the lumens and not abundant in the sperm duct (Figures 59–60).

The tunica albuginea surrounding the testes never thickened seasonally to the degree it did about the ovary.

Even though all females diagnosed as gravid did not necessarily contain ripe eggs and environmental conditions during much of the study were probably not optimal or in some cases tolerable for seatrout, their spawning, and the successful hatching of embryos, enough evidence exists to assume that seatrout have the potential to spawn continually in Mississippi Sound from May through August during most

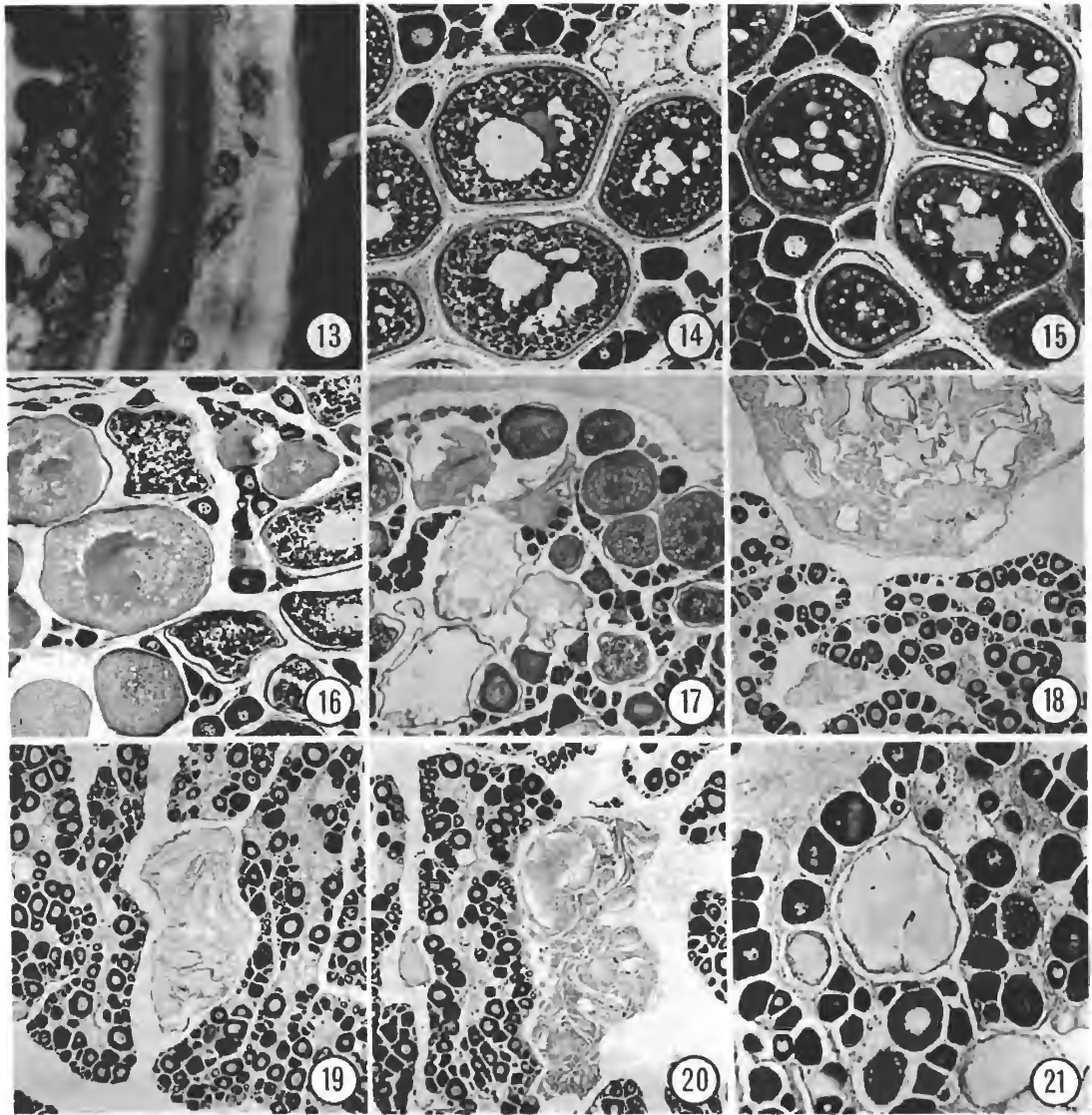
years and also during earlier and later months in exceptional years. Hein and Shepard (1979b) presented a table listing data from 21 sources on spawning seatrout, and, apparently in coastal regions south of Mississippi, ripe fish occasionally occur as early as February and as late as mid November. In the Everglades National Park, Florida, Jannke (1971) observed recently spawned larvae year-around, although their number was reduced during late fall and winter.

The important factors necessary for maturation and spawning seem to be restricted to photoperiod and temperature. Arnold et al. (1976) manipulated those two parameters and ultimately caused a group of spotted seatrout in an approximately 30,000 liter tank to spawn monthly for 13 consecutive months. They recorded 82 spawns during that period when the temperature remained at about 26°C with 15 hr of light and 9 hr of dark each day. Different dual or multiple peaks noted during different years in different regions by a variety of workers, either for individuals or stocks, probably reflect in part those two factors (e.g., Hein and Shepard 1979b).

Given the proper temperature and photoperiod, enough oögonia presumably form and enough oocytes mature in an individual female so that the fish can continually spawn a total of several million eggs over its 4-month or longer spawning period. Colura (personal communication) estimated that a 0.7 kg fish in controlled conditions produced about 250,000 ova per spawn for nearly a year. Eggs are typically buoyant, and Colura (1974) found that those few sinking after experimentally inducing ovulation with injections of human chorionic gonadotropin (HCG) had a lower percentage hatch when compared to 90% of those that were clear, buoyant, and free of follicular tissue. Arnold et al. (1976) assumed that the naturally spawned eggs which sank in their seawater system either died or had not been fertilized. Eggs presumably also sink in low salinity water.

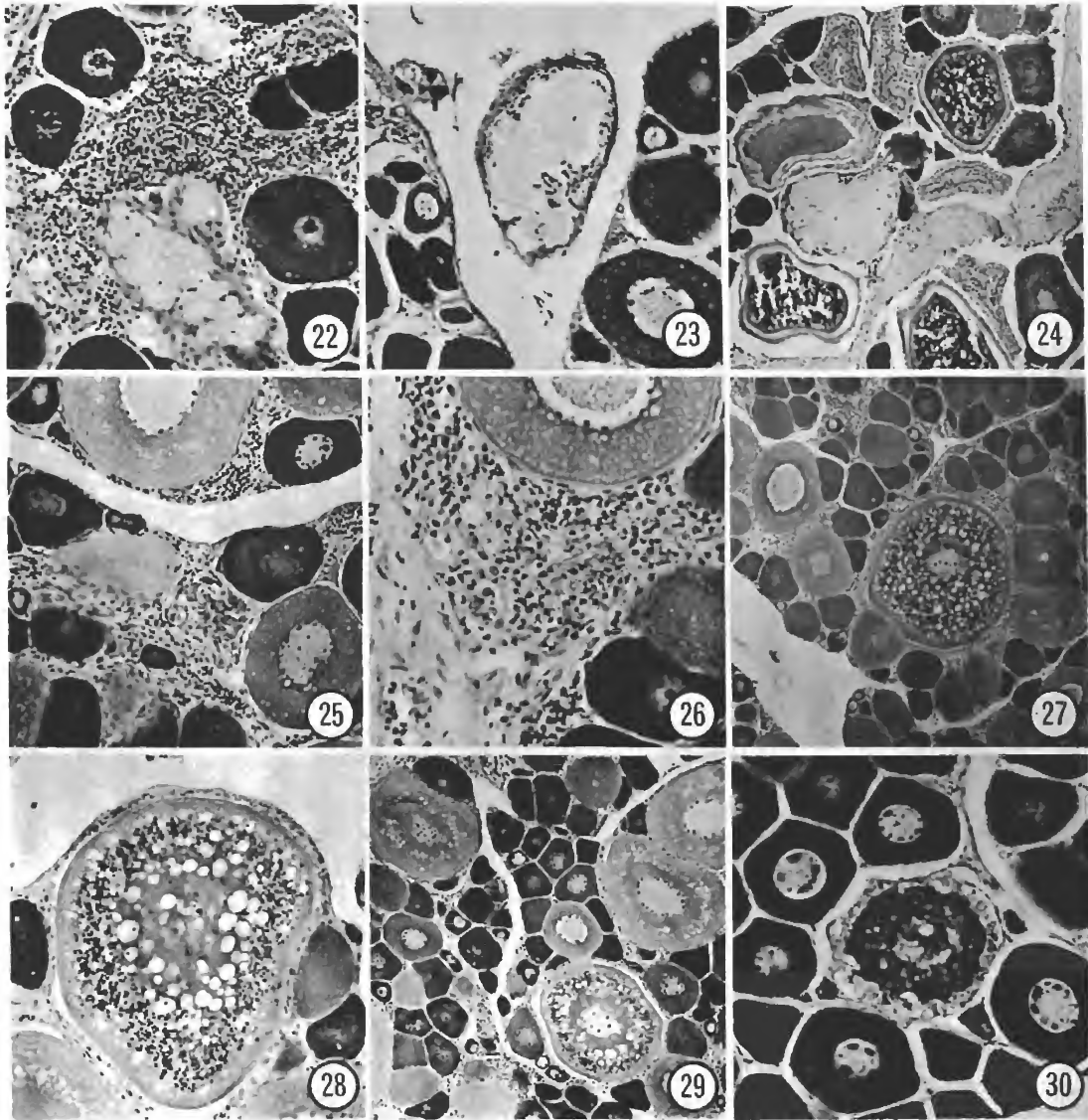
The number of juvenile seatrout does not necessarily correspond to the number of eggs spawned, fertilized, or hatched. Temperature, salinity, food, and other factors influence that production. When Colura (1974) reared seatrout at 23.5°C, assimilation of the yolk sac occurred by 96 hr and most fish died at that time without metamorphosing. The few that lived for 13 days apparently could not utilize the available food. On the other hand, those reared at 28°C hatched sooner (15 rather than 22 hr), developed faster, utilized the same food available to the others, and metamorphosed. Taniguchi (1980) predicted 100% survival of both eggs and newly hatched larvae between 23.1 and 32.9°C over a salinity range of 18.6 to 37.5 ppt. He determined that optimum

the intense reddish-violet staining property of the ooplasm at the periphery and surrounding the nucleus (probably pallial substance of Balbiani's vitelline body). 10. A developing III fish in August showing several oocytes simultaneously undergoing progressive stages of development as well as showing spent follicles. 11. Close-up of oocyte showing medium-sized yolk globules (vitelline granules; additional reddish-staining granules too small to see at this magnification occur abundantly, especially toward periphery), medium-sized yolk vesicles (including lipid material), and a nucleus with an irregular boundary, presumably allowing for increased RNA transportation from nucleoli to ooplasm. Note larger yolk globules in the adjacent, more-developed oocytes. 12. A more developed oocyte than in Figure 11 showing relatively even dispersal of yolk globules and yolk vesicles.

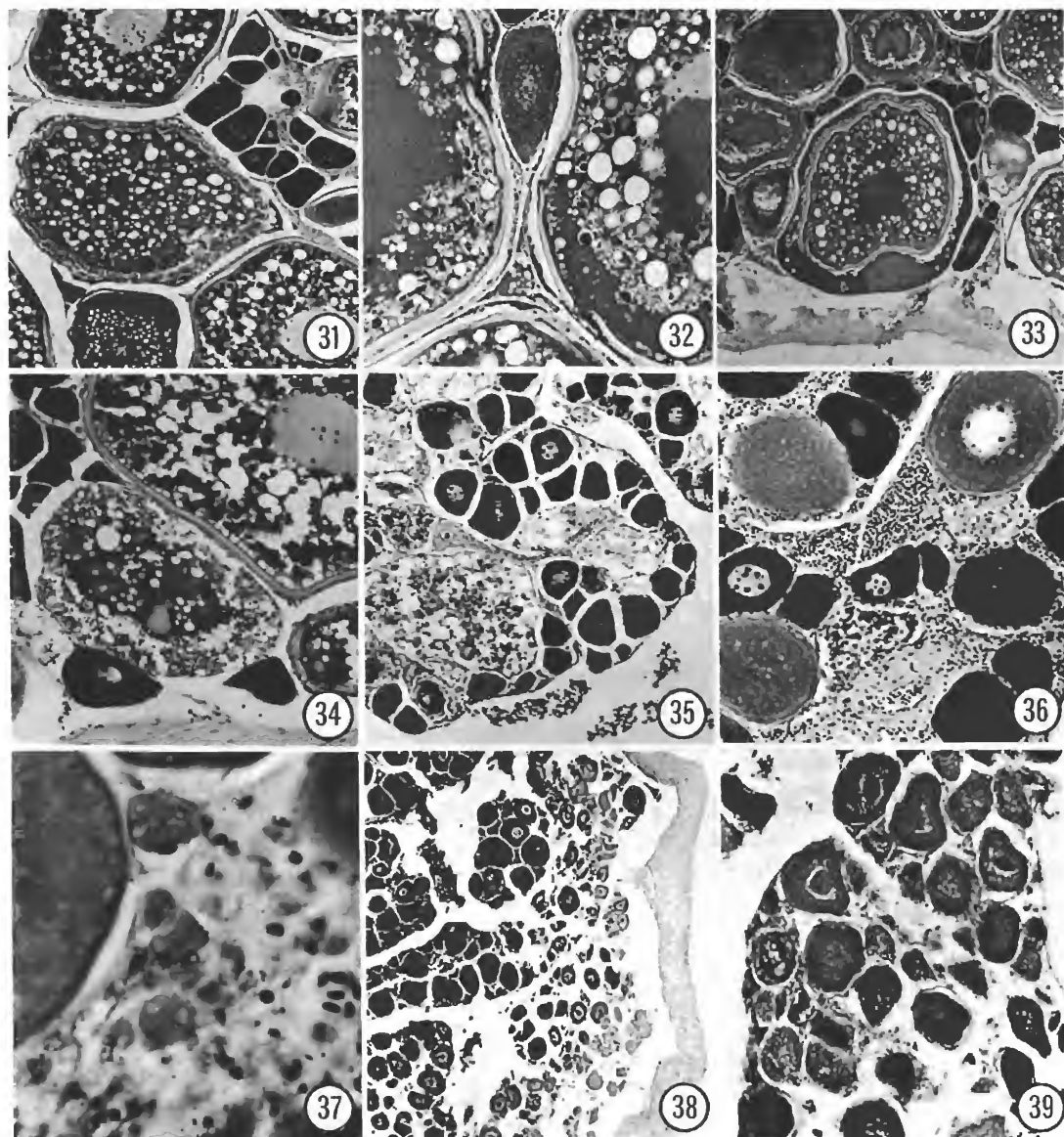


Figures 13–21. Sectioned ovarian tissue from *Cynoscion nebulosus*. 13. Close-up of zona pellucida (= zona radiata) showing periodicity of vertical striations. Note the ooplasm on the inside and the follicular epithelium bounded by theca abutting two oocytes externally. 14. Nearly ripe oocytes from gravid ovary in June with coalescing yolk vesicles forming large, central, yolk and lipid droplet and yolk globules coalescing throughout ooplasm. 15. Oocytes of different gravid fish in June, possibly with atypical or abnormal maturation, showing yolk vesicles coalescing, but vitellogenesis progressing differently than in oocytes in Figure 14 and in other ovaries. Fine yolk globules are abundant near periphery. 16. Nearly ripe oocytes in gravid ovary during August. 17. Ripe and nearly mature oocytes in September as well as spent follicles containing fluid or appearing nearly empty. 18. Portion of large residual mass of spent follicles and unspawned hydrated ova in lumen of spent ovary in September. A leukocytic reaction involves the peripheral area. Note numerous spent follicles occurring in lamellae. 19. A post-spawning residual mass of compacted, hydrated oocytes between lamellae. Note spent follicles in lamellae. 20. A degenerating residuum similar to that in Figure 19 with some vascularization internally. 21. Section from an ovary misdiagnosed as gravid in November because of numerous hydrated, unspent ova within lamellae.

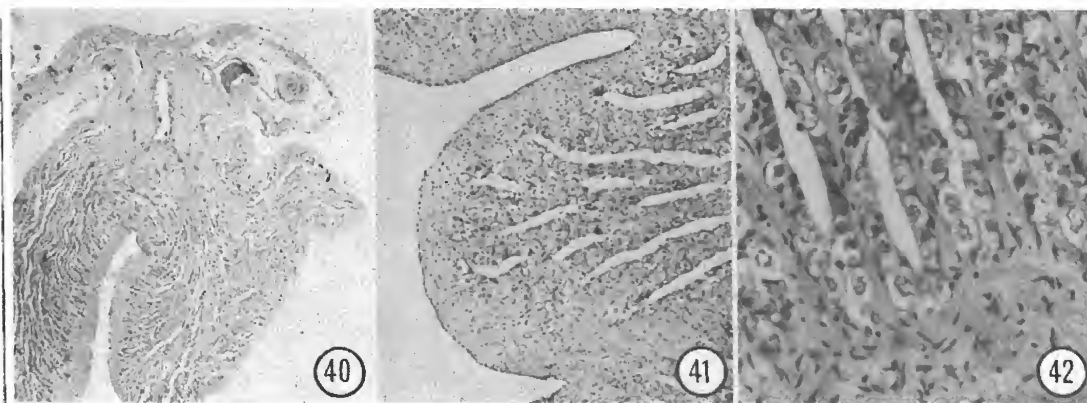




Figures 22–30. Sectioned ovarian tissue from *Cynoscion nebulosus*. 22. Close-up of inflammatory cells invading atretic, unspent ova similar to those shown in Figure 21. 23. A degenerating hydrated ova similar to that in Figures 21–22, but occurring in lumen. 24. Collapsed, spent, follicular epithelial layers adjacent to degenerating ova as well as oocytes in various stages of development during September. 25. Spent fish in July showing inflammatory focus locating spent follicle. 26. Close-up of a different inflamed focus. The space separating ooplasm from nucleoplasm in large, upper oocyte contains vacuolar material rather than representing a fixation artifact. 27. A yolk globule stage oocyte that will probably undergo atresia. 28. A similar oocyte to that shown in Figure 27, but bordering lumen. Note poorly defined zona pellucida and central, fused, yolk globular material associated with relatively small, rather than large, yolk globules. 29. A rare yolk-globule stage oocyte among a variety of stages of oocytes in a spent fish in July. In contrast to the ovaries shown in Figures 27 and 28, this one would probably have produced more mature ova later in the summer. 30. Oocyte that had apparently undergone premature development exhibiting atresia in a developing 111 fish in April. Note abundant lipid vacuoles at periphery.



Figures 31–39. Sectioned ovarian tissue from *Cynoscion nebulosus*. 31. An oocyte (central large one) of a gravid fish in August undergoing early process of atresia. The zona pellucida is present, but fractured into small pieces. 32. Fragmented zona pellucida in two adjacent well-developed oocytes of small gravid fish in July. Note the small amount of yolk material leaking through fracture. 33. One of several oocytes in same ovary as Figure 32 with yolk material and nucleus that had leaked through fracture. Note invasion into leaked yolk by follicular cells. 34. An atretic oocyte in a more advanced state than that in Figure 31 from a fish nearly ready to spawn. Note the apparent lack of a zona pellucida and follicular investment. 35. A spent ovary in September with several oocytes in advanced stages of atresia. Note debris in lumen. 36. Ovary from a resting stage III fish in August exhibiting high degree of vascularity and absorption of oocytic materials. 37. Close-up of same ovary as in Figure 36 showing absorbed material, apparently proteinaceous and intracellular. Whereas clear-yellowish with numerous minute vacuolar areas suggesting lipid components, this material stains lavender using AFIP method for lipofuscin. Other products of a lipid nature occurred nearby as shown by washed-out vacuoles. 38. An abnormal ovary of a developing III fish in October in which a portion was degenerating. The upper left portion extends into normal-appearing “resting oocytes,” whereas those on the right are degenerate or necrotic, resulting in a hard, stiff ovary. 39. A close-up of degenerating oocytes and associated tissues from ovary shown in Figure 38.



Figures 40–42. Sectioned testicular tissue from *Cynoscion nebulosus*. 40. Low-power view of the branching unrestricted spermatogonial type of testis of maturing virgin, 282 mm SL fish in December showing a lack of active spermatogenesis. 41. Testis of developing III, 325 mm SL fish in January without spermatozoa in tubular lumens. 42. Close-up of testis used for Figure 41 showing stages of spermatocytogenesis in cysts surrounded by Sertoli cells.

temperature and salinity for yolk-sac larvae were 28.0°C and 28.1 ppt, respectively. Arnold et al. (1976) achieved satisfactory hatching of seatrout in 25 to 30 ppt, and Colura (personal communication) found a lower percentage hatched in 14 ppt than in 18 ppt. After hatching occurred, those larvae that hatched in 30 ppt could withstand salinities above 10 ppt. On the other hand, salinity of water where adults live and spawn in Mississippi and elsewhere often drops below 10 ppt, and that salinity presumably determines or influences survival of larvae as well as young juveniles. As with all animals, the quality of food influences growth and survival as does its quantity (Arnold et al. 1976, Taniguchi 1980). Mortalities in rearing facilities seemed to result largely from cannibalism (Arnold et al. 1976, Fable et al. 1978).

#### Migration

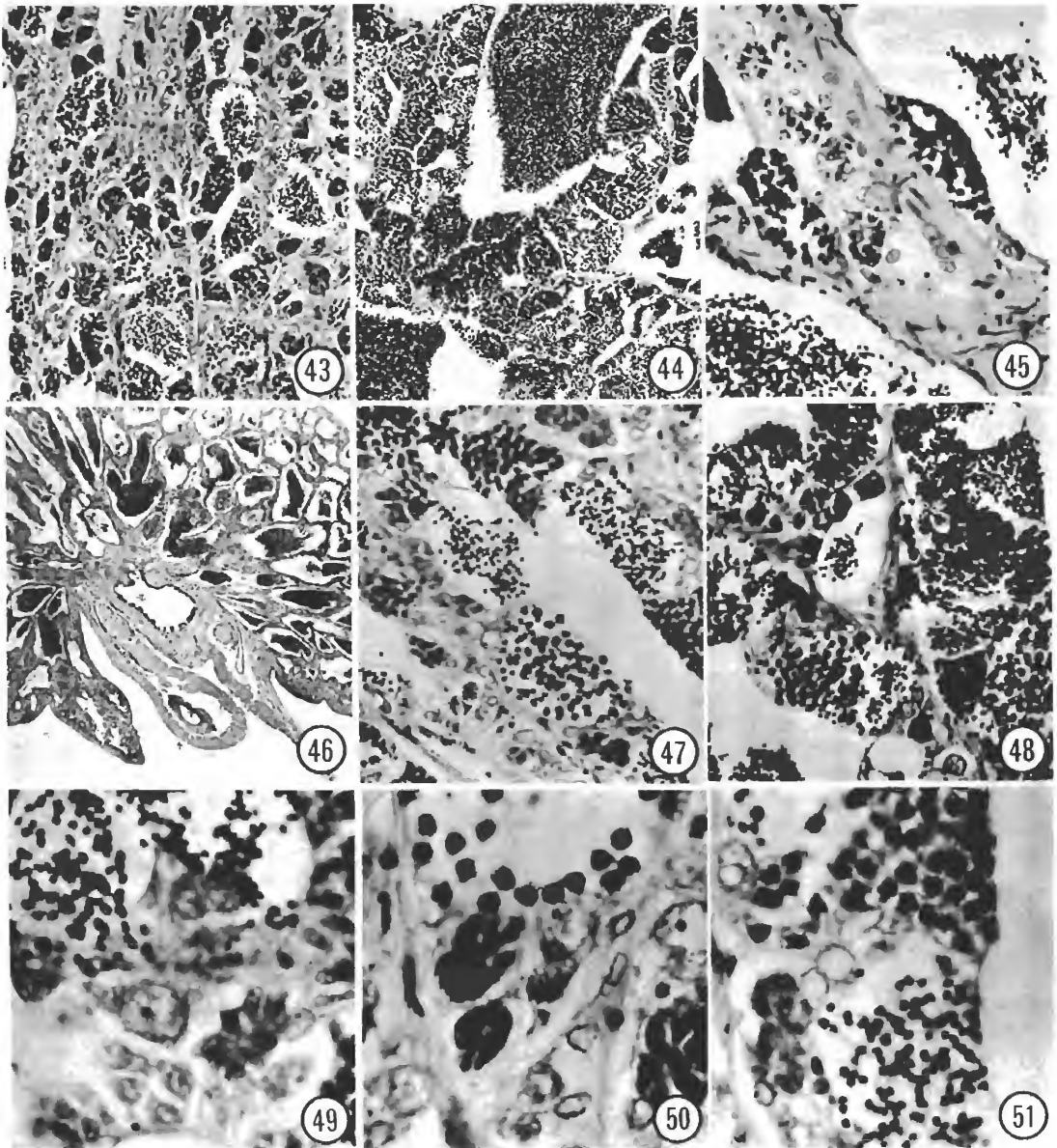
Tagged specimens of *Cynoscion nebulosus* as well as some of the sympatric *C. arenarius* suggest little movement by the two seatrouts within Mississippi Sound. Fourteen tag returns from 133 (10.5%) tagged spotted seatrout consisted of five fish 138 to 416 mm SL caught within a km of their release after 15 to 110 days, two fish 344 and 347 mm long caught there the same day, six fish 137 to 278 mm long that traveled a minimum of 4 to 15 km in 134 to 536 days with the two fish free over a year only 6 and 10 km away, and one fish 262 mm long that was recaptured 25.5 km away after 296 days. A 343 mm fish tagged 18 October 1982, after the 31 December 1981 date when data were no longer included in this report, moved at least 22 km in 23 days.

A relatively small number of specimens was tagged, primarily because abnormal environmental conditions resulted in a near absence of fish during many months; most fish caught were used to obtain data provided elsewhere in this study. I plan additional tagging in the future which, with

concurrent catch data, should help explain seasonal movements, and I also include below data on *C. arenarius* for comparative purposes. Local people returned tags or data on 12 of 320 (3.8%) tagged specimens of *C. arenarius*. Eight fish 148 to 270 mm SL were caught 1 km or less from where they were tagged and released 3 to 67 days earlier. Three others, 222, 143, and 142 mm SL, moved a minimum of 3, 7, and 12 km, respectively, within the same time frame. Another tag from a sand seatrout was found in the stomach of a spotted seatrout 17 km from where the former fish was tagged 97 days earlier.

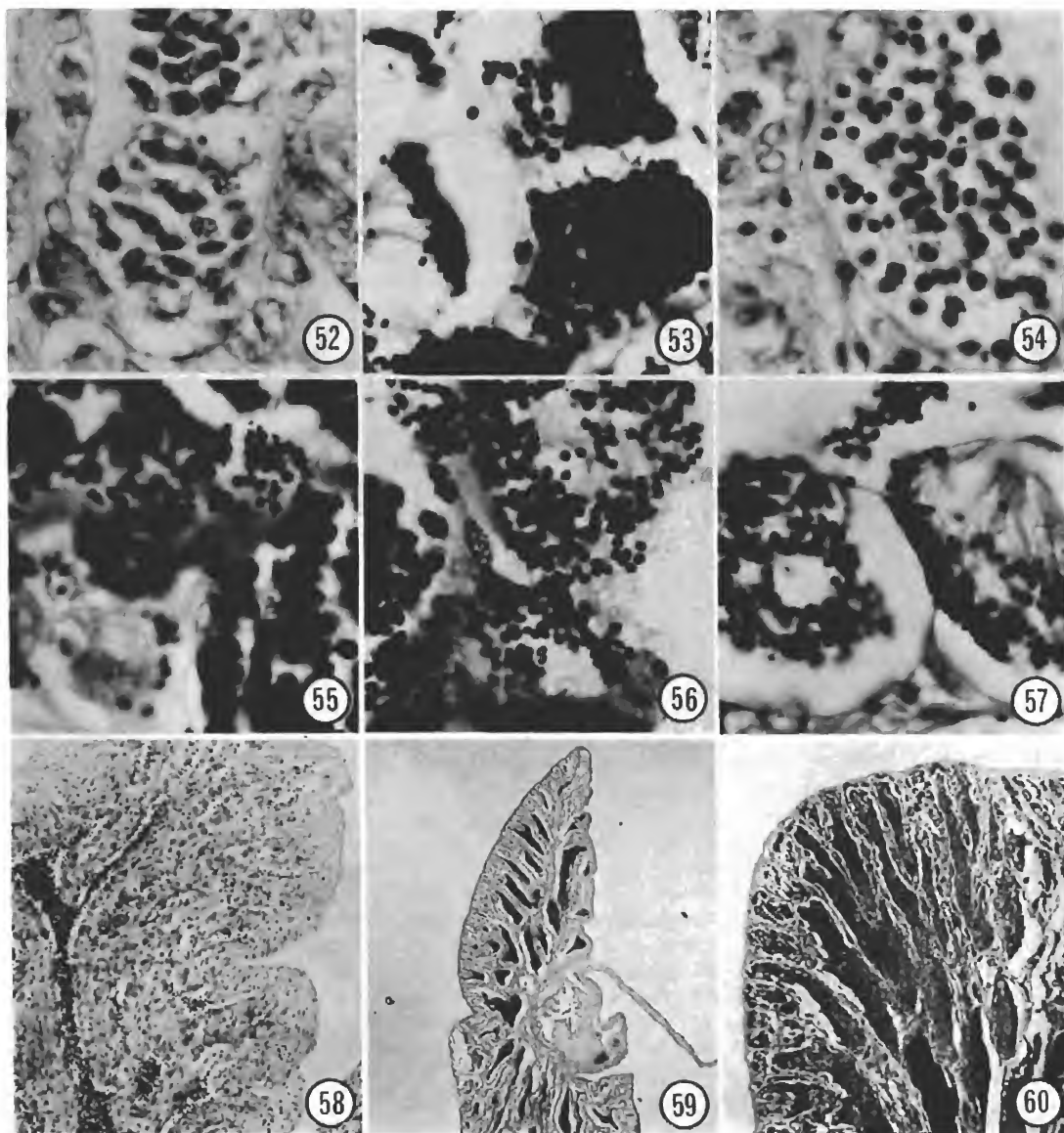
Movement within the Mississippi Sound region appears restricted and related to temperature and salinity changes, foraging behavior, and perhaps spawning. The apparent tendency for some individuals to school by sex during their spawning season as described earlier may have been unusual, but the migration is not. Fishermen in Mississippi and adjacent Louisiana recognize seasonal migrations and associate them with seasonal changes in temperature and salinity. Evidence, however, is lacking to support any movement of the stock in the Sound to leave the general area or any immigration of fish from elsewhere. During cold periods, at least many individuals occupy relatively deep holes and channels in the Sound and bayous.

Numerous reports from Florida on tagging and growth suggest the existence of different stocks that seldom moved far (e.g., Iversen and Tabb 1962). Moffett (1961) reported on three stocks and found 95.3% of 470 returns were caught within 48 km of their release. Of the 16 fish that ended up farther than 145 km, four moved at least 388 km and one moved 507 km. Beaumariage (1969) reported on 537 returns and agreed that seatrout rarely moved as far as 32 to 48 km from their site of release. Of 95 returned fish (1.3%) in Louisiana, all but three were captured less than 3 km away



Figures 43–51. Sectioned testicular tissue from *Cynoscion nebulosus*. 43. A developing 111 fish in March showing active spermatogenesis in the still compact continuous unrestricted spermatogonial testes. Relatively few spermatozoa are being produced during this period. 44. Gravid testis in 419 mm SL fish in May showing lumens of tubules expanded with spermatozoa. 45. Close-up of 455 mm SL fish in September showing spermatogonia and spermatocytes as well as spermatozoa in tubule lumens. 46. A spent, 222 mm SL fish in September with residual spermatozoa abundant in tubule lumens, but nearly absent in spermatic duct. 47. Primarily early stages in developing 111 fish in March. Note lack of spermatozoa in tubule lumens. 48. Close-up showing all stages of spermatogenesis in cysts from fish that had recently become gravid in May. 49. Primary and secondary spermatogonia among Sertoli cells. 50. Spermatogonia through secondary spermatocytes. 51. Spermatogonia through spermatids.





Figures 52–60. Sectioned testicular tissue from *Cynoscion nebulosus*. 52. Vacuolated spermatocytes. 53. Relatively large primary spermatocytes adjacent to smaller secondary spermatocytes. 54. Secondary spermatocytes undergoing fission to form spermatids. 55. Residual bodies being cast off from spermatids. Some appear to be ingested by Sertoli cells. 56. Leydig cells along basement membrane, with their relatively large basophilic nucleus. Note apparent ingesta in centrally located Sertoli cell. 57. Germinal cysts with spermiogenesis in progress. Note adjacent late secondary spermatocytes in left of field. 58. Testis of a "virgin," 214 mm SL fish in September showing spermatozoa in tubule lumens. 59. A developing III, 265 mm SL fish in September with spermatozoa primarily in tubule lumens, but some in spermatic duct. 60. A small peripheral portion of testis of 325 mm SL fish still gravid in September.

from where they were tagged; one was caught 40 km away and another occurred in a deep bayou following a cold front (Adkins et al. 1979). In Texas, tagging data collected by Simmons and Breuer, Bryan (1971), and McEachron and Matlock (1980) and summarized in the latter work also do not support long range migration of spotted seatrout. Nevertheless, like in Mississippi and Louisiana, fish appear to be absent from specific areas during specific periods. McEachron and Matlock (1980) speculated that fish move out of Bastrop Bayou in the Galveston Bay system in late autumn, return in early spring, move out again in late spring and return in early autumn. Based on tags from 57 recaptured fish that had been tagged at least 14 days, the average distance the fish were caught from the point of tagging in Bastrop Bayou was 24 km and the maximum was 122 km. Of those returns, 75% came from the Galveston Bay system, and 19% came from shallow Gulf of Mexico sites during summer. Whereas Bryan (1971) noted that 11 of 17 spotted seatrout tagged in Arroyo Colorado (lower Laguna Madre) and free for over 150 days were recaptured within 7 km of their tagging site, if he would have recognized those fish free for over 30 days, he would have noted about 22% of them to be more than 22 km from the site and only about 27% less than 7 km. Simmons and Breuer found that only 5 to 6% of the spotted seatrout tagged during 1950 to 1970 in Galveston, Matagorda, and Aransas bays were recaptured farther than 32.2 km, but that 11 to 16% had moved at least that far in San Antonio Bay, Corpus Christi Bay, and lower Laguna Madre and that 50% reflected the movement in upper Laguna Madre. Moreover, they used Monel jaw tags which usually do not remain in fish as long as abdominal anchor tags used in later efforts.

#### *Parasites, Diseases, Mortalities, and Abnormal Conditions*

Only representative fish underwent a critical examination for parasites. In some cases, fish during specific periods were examined for specific parasites (e.g., Overstreet 1977, Deardorff and Overstreet 1981), and in others conspicuous parasites were noted. Nevertheless, records of those occasional parasites encountered in or on *C. nebulosus* plus those infecting the related *C. arenarius* occur in Table 20 along with numerous other records obtained from the literature. For some, but not all, records where misidentifications are suspected or where "group names" are used, the name has been placed between quotation marks. A group name applies to similar-appearing larvae that when mature can be separated into more than one species, the identifications of which are not presently known.

Not on the list are a variety of microbial symbionts, some of which are pathogenic or potentially pathogenic if given the proper set of conditions. I have seen the viral disease lymphocystis on both *C. nebulosus* and *C. arenarius* in Mississippi Sound. Infecting connective tissue cells in the fins and body proper, the virions of lymphocystis disease cause hypertrophy, resulting in readily visible masses of hyaline-

encapsulated cells (Howse and Christmas 1970). Cell lines cultured from both *C. nebulosus* and *C. arenarius* support replication of the lymphocystis organisms (Middlebrooks et al. 1979, 1981). Presence of the disease in nature may indicate or help identify a polluted environment (Edwards and Overstreet 1976, Overstreet and Howse 1977, Sindermann 1979).

Several species of bacteria probably always occur on or in seatrout in their natural habitats. Whereas most species have no detrimental effect on the host, some cause disease or secondary infections, and others can cause disease in man if he eats the product inadequately prepared. Keel and Cook (1975) detected *Vibrio parahaemolyticus*, an agent of food poisoning, in oyster, shrimp, and fish samples in Mississippi, and it probably occurs in seatrout. The spotted seatrout has a predisposition for "fin rot syndrome," a term for certain nonspecific lesions (Overstreet and Howse 1977, Sindermann 1979). In those fishes examined in Mississippi, which included more than the spotted seatrout, pseudomonads, vibrios, and occasionally aeromonads occurred in affected individuals (Overstreet and Howse 1977). Adkins et al. (1979) reported that seatrout from a kill associated with low temperatures in February 1978 had lesions and abrasions contaminated with fungi and bacteria. Bacterial diseases probably have a great impact on egg and larval stages. As evidence, Shelbourne (1964) noted improved hatching and survival of larvae of another species concurrent with use of antibiotics or a combination of antibiotics and irrigation with ultraviolet-treated seawater.

Algae occasionally cause infections or disease in animals. Reports of their presence in fishes are uncommon (Edwards 1978) and in marine fishes are rare (Blasiola and Turnier 1979). In one case on 5 March 1973, a unicellular alga occurred in the flesh of a 428 mm SL female specimen of *C. nebulosus* caught off Front Beach, Ocean Springs. The agent fluoresced red; not restricted to a specific site, it occurred next to the integument, throughout the flesh, and adjacent to the vertebral column (Figures 61-62).

In addition to certain microbial infections, some protozoan and metazoan infections can also harm and even kill the seatrout hosts as well as allow secondary infections. Some affect larvae or juveniles, whereas others affect adults. Some only harm their hosts seasonally or when maintained in crowded conditions such as occur in aquaculture. Adkins et al. (1979) reported that a protozoan on the gills caused disease during a period of prolonged low temperature which allowed the seatrout to become more susceptible to fungal and bacterial infections. Many of those fish died and washed ashore.

Most parasites that kill or severely harm their hosts in nature have been observed or recognized only rarely because when a fish dies or becomes weakened, a predator or scavenger rapidly eats it. Rosenthal (1967) showed that larval herring reared with wild plankton became infected with the

TABLE 20.  
Partial list of parasites from *Cynoscion nebulosus* and *C. arenarius*.

Parasite	Cn	Ca	Site	Geographical locality	Reference
Sarcomastigophora					
Dinoflagellida					
<i>Amyloodinium ocellatum</i> (Brown 1931)	X		Gills	Mississippi	Lawler (1980)
		X		Mississippi	Present study
	X	X		Experimental infection	Lawler (1980)
Apicomplexa					
Coccidia					
<i>Haemogregarina</i> sp.	X		Leucocytes	Lemon Bay, FL	Saunders (1954)
Microspora					
Microsporidia					
<i>Pleistophora</i> sp.	X	X	Liver	Mississippi	Present study
Myxozoa					
Myxosporea					
<i>Kudoa</i> sp.		X	Muscle tissue	Mississippi	Present study
<i>Henneguya</i> sp.	X	X	Dorsal and caudal fins	Mississippi	Overstreet (1978), Present study
Ciliophora					
Peritrichia					
? <i>Trichodina</i> sp.	X	X	Gills	Mississippi	Present study
Cestoda					
Tetraphyllidea					
" <i>Scolex polymorphus</i> "	X		Cystic duct, intestine	Beaufort, NC	Linton (1905)
	X	X	Cystic duct, intestine	Mississippi, Louisiana	Present study
" <i>Scolex</i> sp., type small"	X	X	Intestine, rectum	Mississippi, Louisiana	Present study
" <i>Scolex</i> spp., type large"	X	X	Pyloric ceca, intestine, rectum	Mississippi, Louisiana	Present study
<i>Rhinebothrium</i> sp.		X	Intestine	Mississippi	Present study
Tetrarhynchea					
<i>Poecilancistrum caryophyllum</i> (Diesing 1950) metacestode	X		Muscle	Texas	Chandler (1935), Schlicht and McFarland (1967)
(some ref. as <i>P. robustum</i> )				Florida	Hutton and Sogandares-Bernal (1960), Goldstein (1963), Hutton (1964)
				Louisiana	Boertje (1976), Adkins et al. (1979)
	X	X		Texas, Louisiana, Mississippi, Florida	Overstreet (1977, 1978)
<i>Nybelinia bisulcata</i> (Linton 1889) (as <i>Tetrarhynchus</i> b.) metacestode	X		Stomach wall	Beaufort, NC	Linton (1905)
<i>Nybelinia</i> sp. metacestode		X	Stomach wall	Mississippi	Present study
<i>Otobothrium crenacolle</i> Linton 1890	X	X	Submucosa of stomach	Beaufort, NC	Linton (1905)
	X	X	Mesentery	Mississippi	Present study
" <i>Rhynchobothrium</i> sp."	X		On viscera	Beaufort, NC	Linton (1905)
Tetrarhynchea sp. metacestode	X		Muscle	Mississippi, Louisiana	Overstreet (1977)
Monogenea					
Diclidophoridae					
<i>Neoheterobothrium cynoscioni</i> (MacCallum 1917) (as <i>Choriocotyle reynoldsi</i> ) (as <i>Choriocotyle</i> c.)	X		Gills	Norfolk, VA	Frayne (1943)
	X	O	Gills	Alligator Harbor, FL; Grand Isle, LA	Hargis (1955b), Thatcher (1959)
	X	X	Mouth, gills, skin	Mississippi	Present study
Diplectanidae					
<i>Diplectanum bilobatum</i> Hargis 1955	X		Gills	Alligator Harbor, FL; Grand Isle, LA	Hargis (1955a)
	X			Grand Isle, LA	Thatcher (1959)
	X		Gills	Mississippi	Present study

TABLE 20 (Continued)

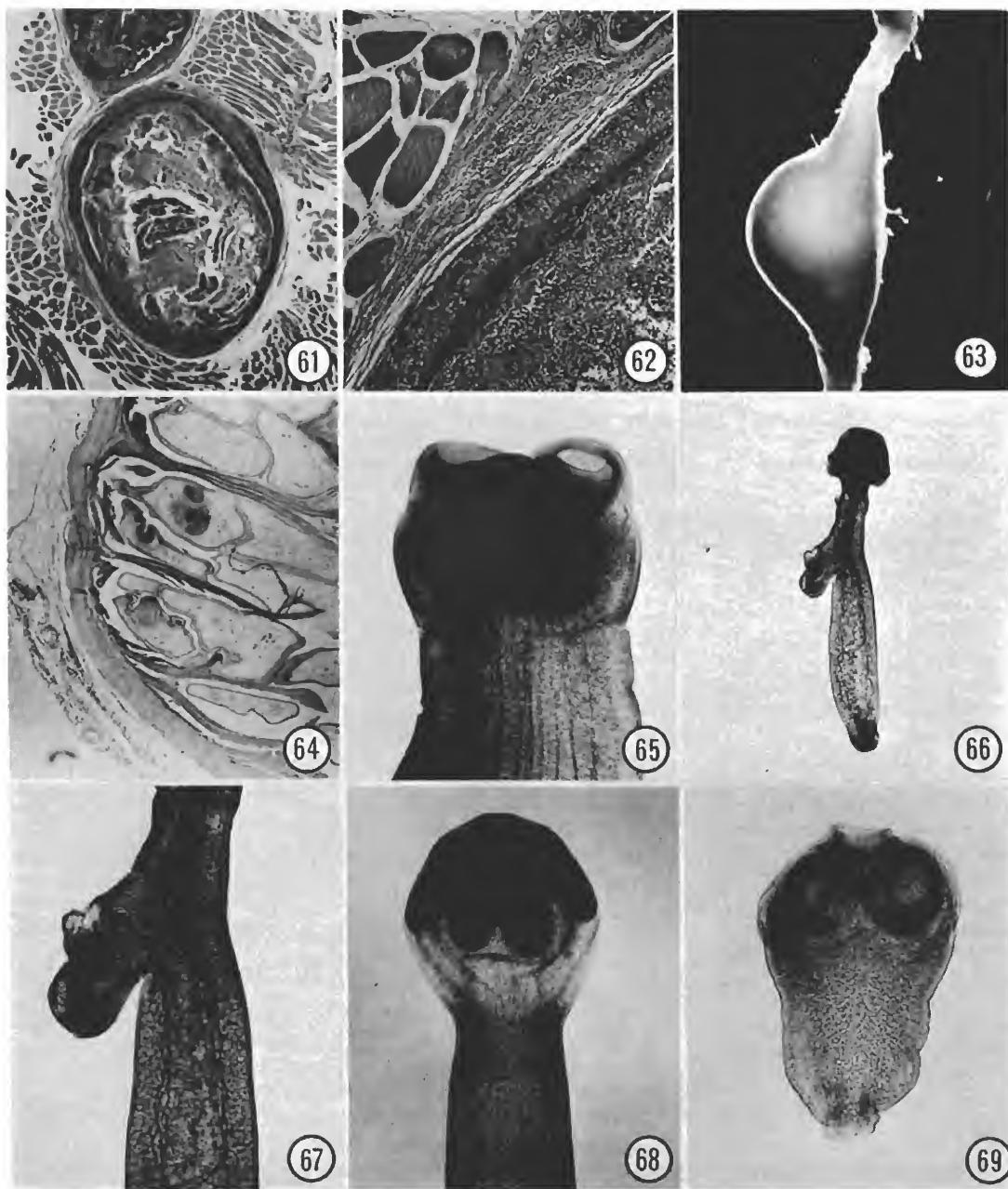
Partial list of parasites from *Cynoscion nebulosus* and *C. arenarius*.

Parasite	Cn	Ca	Site	Geographical locality	Reference
<b>Microcotylidae</b>					
<i>Cynoscionicola heteracantha</i> (Manter 1938)	X		Gills	Beaufort, NC	Linton (1905), Manter (1938)
(some ref. as <i>Microcotyle h.</i> )	X		Gills	Alligator Harbor, FL	Hargis (1956)
	X		Gills	Grand Isle, LA	Thatcher (1959)
	X		Gills	Mississippi	Present study
<b>Udonellidae</b>					
<i>Udonella caligorum</i> Johnston 1835	X		Mouth and skin, typically on <i>Caligus praetextus</i>	Mississippi Sound	Overstreet (in press), Present study
spoiled monogeneans	X	X		Port Aransas, TX	Koratha (1955)
<b>Digenea</b>					
<b>Acanthocolpidae</b>					
<i>Stephanostomum interruptum</i> Sparks and Thatcher 1958	X		Intestine	Grand Isle, LA and Port Aransas, TX	Sparks (1958), Sparks and Thatcher (1958)
	X	X	Intestine	Alligator Harbor, FL	Nahhas and Short (1965)
	X	X	Intestine, rectum	Mississippi	Present study
<i>Stephanostomum imparispine</i> (Linton 1905)	X			South Carolina?	Lawler (1978)
" <i>Stephanostomum tenue</i> "	X			North Carolina	Linton (1905)
<i>Stephanostomum</i> sp. metacercaria (as <i>S. valde-inflatum</i> )	X		Cysts on viscera	Beaufort, NC	Linton (1905)
<b>Aporocotylidae</b>					
<i>Cardicola laruei</i> Short 1953	X	X	Heart	Alligator Harbor; St. George Island, FL	Short (1953), Nahhas and Short (1965)
<b>Bucephalidae</b>					
<i>Bucephalus cynoscion</i> Hopkins 1956	X			Grand Isle, LA	Hopkins (1956)
	X	X			Sparks (1958)
	X	X	Pyloric ceca, intestine, rectum	Barataria Bay, LA; Mississippi	Corkum (1967), Present study
<i>Bucephaloides caecorum</i> Hopkins 1956	X		Pyloric ceca	Grand Isle, LA	Hopkins (1956), Sparks (1958)
	X		Pyloric ceca, upper intestine	Barataria Bay, LA; Mississippi	Corkum (1968)
		X		Galveston Bay, TX	Sparks (1960)
	X	X	Pyloric ceca, intestine	Mississippi	Present study
<b>Cryptogonimidae</b>					
<i>Metadena spectanda</i> Travassos, Freitas, and Bührnheim, 1967 metacercaria		X	Fins, flesh	Mississippi	Present study
<b>Didymozoidae</b>					
Metacercaria	X	X	Stomach	Mississippi	Present study
<b>Diplostomidae</b>					
<i>Posthodiplostomum minimum</i> (MacCallum 1921) metacercaria		X		Louisiana	Arnold et al. (1967)
<b>Gorgoderidae</b>					
<i>Phyllodistomum</i> sp.		X	Urinary bladder	Mississippi Sound	Present study
<b>Hemiuridae</b>					
" <i>Lecithochirium monticellii</i> "	X		Intestine	North Carolina	Linton (1905)
<i>Lecithochirium</i> sp.	X	X	Stomach	Mississippi	Present study
<i>Parahemiurus merus</i> (Linton 1910)	X		Stomach	Alligator Harbor, FL	Nahhas and Short (1965)
<i>Stomachicola rubea</i> (Linton 1910)	X			Sapelo Island, GA	Sinclair, Smith, and Sullivan (1972)
<i>Stomachicola magna</i> (Manter 1931) (as <i>Tubulovesicula</i> sp.)	X		Stomach, air bladder	North Carolina	Manter (1931)
	X	X	Beneath ovarian membrane, in body muscles	Alligator Harbor, FL	Loftin (1960), Nahhas and Short (1965)
	X	X	Body cavity, muscles, stomach wall	Mississippi	Present study
Immature hemiurids	X			Grand Isle, LA	Sparks (1958)

TABLE 20 (Continued)  
 Partial list of parasites from *Cynoscion nebulosus* and *C. arenarius*.

Parasite	Cn	Ca	Site	Geographical locality	Reference
<b>Hirudinellidae</b>					
<i>Hirudinella ventricosa</i> (Pallas 1774) metacercaria		X	Body cavity	Round Island, Mississippi Sound	Present study
<b>Pleorchidae</b>					
<i>Pleorchis americanus</i> Lühe 1906	X	X	Intestine	West coast of Florida	Sogandares-Bernal and Hutton (1959), Hutton and Sogandares- Bernal (1960), Loftin (1960), Hutton (1964), Nahhas and Short (1965), Nahhas and Powell (1971)
		X		Grand Isle, LA	Sparks (1958)
	X	X	Intestine, pyloric ceca	Mississippi, Louisiana	Present study
<b>Nematoda</b>					
<b>Anisakidae</b>					
? <i>Hysterothylacium reliquens</i> (Norris and Overstreet 1975) larva	X	X	Mesentery	Mississippi	Deardorff and Overstreet (1981)
<i>Hysterothylacium</i> type MB larva	X	X	Mesentery	Mississippi Sound, Gulf of Mexico	Deardorff and Overstreet (1981)
<i>Hysterothylacium</i> type MD larva	X		Mesentery	Mississippi	Deardorff and Overstreet (1981)
" <i>Ascaris</i> sp." larva	X		On viscera, mesentery	North Carolina	Linton (1905)
<b>Camallanidae</b>					
<i>Spirocamallanus cricotus</i> Fusco and Overstreet 1978	X	X	Intestine	Mississippi	Present study
<b>Philometridae</b>					
Undescribed Philometrinae	X		Encapsulated in mouth	Mississippi	Present study
<b>Incertae sedis</b>					
" <i>Agamonema</i> sp."		X		Louisiana	Arnold et al. (1967)
<b>Annelida</b>					
<b>Hirudinea</b>					
<i>Malmiana philotherma</i> Sawyer, Lawler, and Overstreet 1975		O	Gills	Mississippi	Present study
<b>Copepoda</b>					
<b>Anthosomidae</b>					
<i>Lernanthropus gisleri</i> van Beneden 1852	X		Gills	Grand Isle, LA; Port Aransas, TX; Tuxpan, Mexico	Causey (1953a, 1953b)
				West Florida	Bere (1936)
				Texas	Pearse (1952)
<i>Lernanthropus pomatomi</i> Rathbun 1887	X		Gills	Texas	Causey (1953b)
<i>Lernanthropus pupa</i> Burmeister 1833	X		Gills	Texas	Causey (1953b)
<b>Caligidae</b>					
<i>Caligus bonito</i> Wilson 1905	X			Laguna Madre, TX	Simmons (1957)
<i>Caligus praetextus</i> Bere 1936	X		Gills	Texas	Causey (1953b), Present study
<i>Caligus rapax</i> Edwards 1840 (as <i>C. repax</i> )	X	X		Laguna Madre, TX	Simmons (1957)
<i>Caligus sciaenops</i> Pearse 1952	X		Roof of mouth	Texas	Pearse (1952)
<i>Caligus</i> sp. larva	X		Usually dorsum	East Florida (laboratory)	Houde (1972)
<b>Pseudocynidae</b>					
<i>Cybicola elongata</i> Pearse 1951	X			Texas	Pearse (1952)
<b>Branchiura</b>					
<i>Argulus alosae</i> Gould 1841	X		Mouth, gills	Mississippi	Cressey (1978), Present study
<b>Isopoda</b>					
<b>Cymothoidae</b>					
<i>Cymothoa excisa</i> Perty 1834		O	Gill arches	Grand Isle, LA	Comeaux (1942)
<i>Nerocila acuminata</i> Schioedte and Meinert 1910					
<i>Lironeca ovalis</i> (Say 1818)	X		Gills	Texas	Pearson (1929)
	X		Gills	Mississippi	Present study
<i>Cymothoa exigua</i> Schioedte and Meinert 1884	X		Gill arches	Grand Isle, LA	Comeaux (1942)

Cn = *Cynoscion nebulosus*; Ca = *Cynoscion arenarius*; O = *Cynoscion nothus*.



Figures 61–62. Alga in muscle tissue of *Cynoscion nebulosus*. 61. Low-power view showing relative lack of a widespread associated inflammatory reaction. 62. Close-up of alga showing relationship with muscle tissue.

Figures 63–69. Cestodes in sea trout. 63. Cystic duct of *Cynoscion nebulosus* expanded with apparently harmless infection of "Scolex polymorphus." 64. Cross-section through cystic duct showing a few of the numerous metacystodes of "Scolex polymorphus." 65. Scolex of "normal," 1.35 mm long specimen of "Scolex polymorphus" to show its "polymorphic" character. 66. Specimen of 1.32 mm long "Scolex

larval stage of an ascaridoid nematode, tetraphyllidean cestode, lernaecoid copepod, and *Caligus rapax*. He estimated that those larval parasites, primarily the nematode and lernaecoid, killed about 10% of the actively feeding fish; related parasitic species infect the seatrout (Table 20). When Houde (1972, personal communication) fed wild plankton to larval *C. nebulosus*, the fish became infested with the chalimus stage of *Caligus* sp. which usually attached to the dorsum near the developing dorsal fin, but occasionally elsewhere. Houde noted that a single copepod could kill a Spanish sardine or bay anchovy when the fish was less than about 12 mm long. Fisheries personnel at GCRL have noted numerous specimens of larval, postlarval, and juvenile sciaenid fishes from Mississippi Sound and the northern Gulf of Mexico that have caligid larvae attached.

The most conspicuous external metazoan parasite of seatrouts in Mississippi is the isopod *Lironeca ovalis*. It can destroy a large amount of gill filament (e.g., Overstreet 1983). In fact, it may be responsible for mortalities, especially of juveniles. Pearson (1929) suggested that many such fish among young age-group fish may be "runt" or "constitutionally slow-growing fish during the early years of life, but which are eliminated from the fish stock gradually. . ." He went on to suggest that *L. ovalis*, which commonly occurred on *C. nebulosus* during its first two years, but seldom on older individuals, caused the infested fish to be shorter than uninfested counterparts in their own year classes. In Mississippi, individuals of *C. nebulosus* between 10 and 17 cm long from November through May commonly hosted one or two specimens of the parasite. As noted in Texas by Pearson, larger fish in Mississippi rarely had an infestation.

When crowded in aquacultural conditions, the seatrouts, as well as other fishes, become vulnerable to more diseases than in their natural environment. For those fish in ponds and closed systems where parasites are not continually introduced, parasites and disease-causing agents with direct life cycles cause the most harm. Bacterial diseases in reared seatrout were discussed previously. Over 90% of the spotted seatrout captured by gill net or trammel net and maintained in a pond died within 24 hr. Those that survived 30 days exhibited extensive bacterial infections (Elam 1971). When microbial diseases cause mortality of previously-unstressed fish, the deaths can usually be attributed indirectly to poor water quality. Parasites with direct cycles that cause disease in cultured seatrout include *Amyloodinium ocellatum*, peritrich ciliates, and monogeneans. Of these, the dinoflagellate *A. ocellatum* is the hardest to treat with chemicals. Lawler (1980) introduced a 160 mm TL uninfested fish into an in-

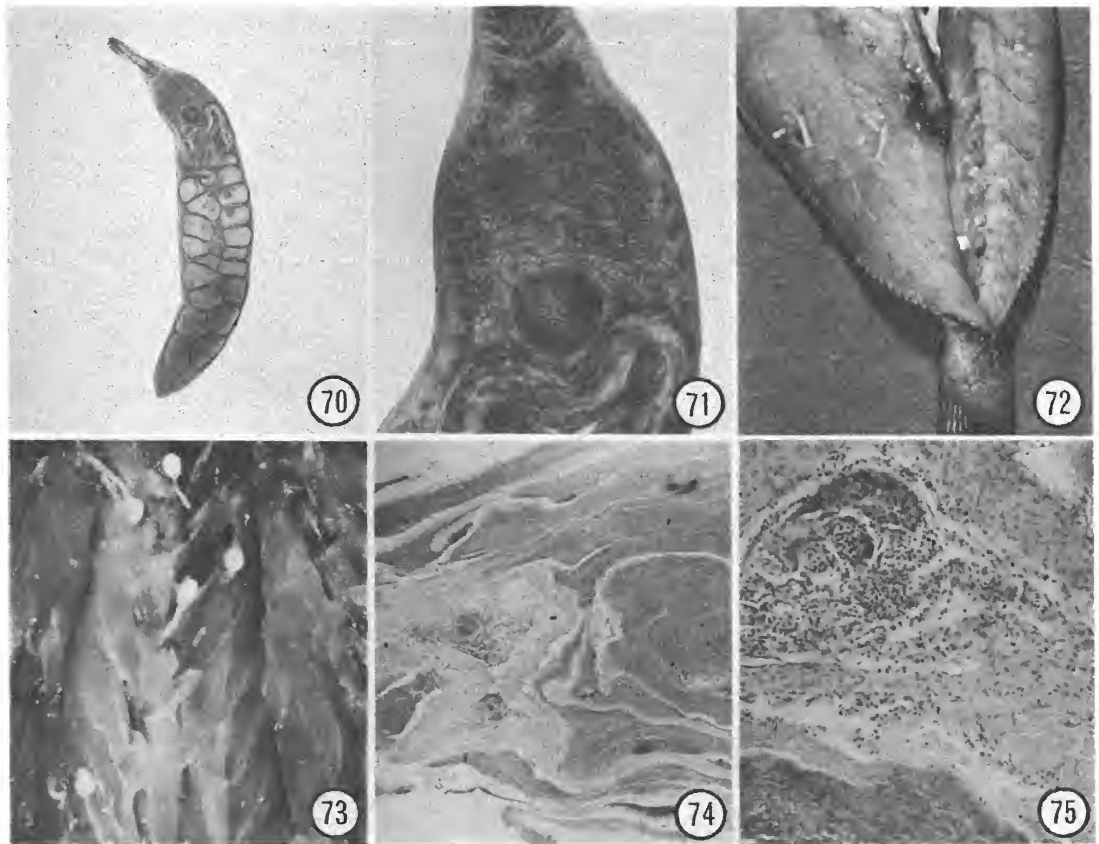
festated system, and it died in 42 hours with from 20 to 50 dinoflagellates per filament.

All parasites do not harm the seatrouts. In fact, most well-adapted parasites would reduce their potential for survival, if as individuals or populations they killed their hosts. A good example of what appears to be a harmless parasite is "*Scolex polymorphus*," a phyllobothriid tetraphyllidean metacestode that occurs in large numbers, sometimes hundreds, within the cystic duct and occasionally in the gall bladder and intestine of its host. Curtis (1911) showed inconclusively that the same or a similar species in *C. regalis*, identifiable as *Phoreiobothrium triloculatum* Linton 1901, developed to maturity in the sand shark. The diameter of the cystic duct can be enlarged several times and packed with the parasite (Figures 63–67), but metabolism appears normal: food in the intestine of infected hosts appeared in a normal state of digestion, and condition coefficients of infected fish appeared "normal." The metacestode stage may be especially unusual in that it may undergo asexual budding, unknown for metacestodes other than the tetrathyridium stage of at least *Mesocostoides corti* Hoeppli 1925 in its second intermediate host (see Voge 1969). I have seen what appears to be more advanced cases of budding in the same or a related cestode from the cystic duct of other fishes. Several small larval helminths occurred in both seatrouts in small numbers that have no adverse effect on their hosts (Figures 68–71).

The metacestode stage of the tetrarhynchian *Poecilancistrum caryophyllum* in the musculature of the spotted seatrout (Figures 72–73) and several other sciaenids does not affect the condition coefficient of adult fish hosts (Overstreet 1977). A possibility exists that if a young fish less than 140 mm SL becomes infected, it dies. Whether this occurs or whether the apparent absence of infection in these small fish can be explained by these fish being spatially or temporally isolated from the preceding infective host remains to be determined. Overstreet (1977) provided data indicating that infected fish larger than 140 mm acquire an immunological response to challenge infections. Consequently, nearly all infected fish smaller than 400 mm in Mississippi had about two worms, whereas those longer had a wide range, but still averaged about 2.5 worms per infected fish. The prevalence gradually increased with increase in fish-length to 100% of fish 50 cm long. In regions of higher salinity such as Apalachee Bay, Florida, and during years with higher than normal salinity, the prevalence and intensity of infections of this parasite which matures exclusively in specific sharks were greater, presumably relating to the availability of infected intermediate hosts.

polymorphus" from cystic duct of *Cynoscion arenarius* showing initial stage of budding. 67. Close-up of specimen in Figure 66 to show that the excretory system of worm-proper is not involved with bulging portion. 68. Scolex of 4.24 mm long "Scolex sp., type large" from pyloric ceca of *Cynoscion arenarius* under slight pressure. Two septa occur in each bothridia. 69. "Scolex sp., type small," 370  $\mu$ m contracted specimen from intestine of *Cynoscion arenarius*.





Figures 70–75. Helminths and lesions in seatrouts. 70. Didymozoid digenean metacercaria, unencysted in lumen of stomach of *Cynoscion nebulosus* from Marsh Point, Ocean Springs. The adult probably occurs encysted in an offshore pelagic fish that feeds on the seatrout. 71. Close-up of digenean in Figure 70 showing characteristic muscular “stomach,” winding esophagus, and glandular forebody. 72. Flesh of *Cynoscion nebulosus* cut from vertebral column showing two metacercariae of *Poecilancistrum caryophyllum*. 73. Close-up of metacercariae of *Poecilancistrum caryophyllum* showing long tubes and bulbous portion enclosing scolex (from Overstreet 1977). 74. Lesion in caudal peduncle of *Cynoscion arenarius*, possibly resulting from injury or degenerated *Stomachicola magna*. Grossly, the lesion appeared as a 1.5 cm confined, chocolate-brownish, soft region. 75. Close-up of lesion in Figure 74. Lesions from predators, fishermen, parasites, and unknown causes occur occasionally in all species of *Cynoscion*.

These few specimens per fish of *P. caryophyllum*, a parasite that does not harm humans, even if eaten raw, result in large numbers of fish being uneaten or discarded. Guest and Gunter (1958), Overstreet (1978), and others discussed the economic loss attributed to infected fish. To better understand which category of people exhibit disgust, I developed a questionnaire for people attending Ocean Springs’ and Biloxi’s fishing rodeos; local, annual, weekend events sponsored by a young men’s organization. Registered fishermen try to catch the largest specimen of a variety of species, and they along with other interested people enjoy food, music, exhibits of fish, and contests of skill and luck.

Nonfishermen answering the questionnaire exhibited more disgust about infections than fishermen. When ques-

tioned directly or indirectly about “wormy trout,” most either were unaware or repulsed by them. Numerous seafood consumers have called GCRL to inquire about the edibility of such fish. Many of these informed people still will not eat infected fish regardless of the harmless nature of the worm. Of 121 questioned fishermen who caught from 30 to over 2,000 individual spotted seatrout per year, 43.8% saw the cestode and did not mind eating infected fish, but some culled the worms. More surprising to me, 24.8% of those fishermen regularly caught infected fish, knew that the fish were infected, and would not eat them. The remaining 31.4% showed no awareness that seatrout had worms, either because they did not fillet the fish or because they assumed the worms were fascia, nerves, or other tissues of the fish. Of the

fishermen who caught fewer than 30 specimens of seatrout per year, some said they did not fish specifically for seatrout because of their worms.

Another parasite that inspires consumer inquiries is *Stomachicola magna*. This hemiurid digenean occurs encapsulated or wandering in the peritoneum, flesh, or viscera. Often surrounded by dark-colored "melanin" pigment which attracts the consumer's eye, this up to 14 mm-long, pinkish-colored worm, with or without eggs, moves if removed from the capsule. A greater prevalence and intensity of infection occurred in *Cynoscion arenarius* than in *C. nebulosus*, but several fishes host this worm (Sinclair et al. 1972, Corkum 1966). No evidence suggests that it can infect or harm man. In fact, no parasite in properly cooked fish can harm people.

A few potential public health problems exist. Disease would probably develop only in those who ate inadequately prepared seatrout or who ate products from an especially polluted area. The seatrout contained at least one nematode, *Hysterothylacium* type MB larva, that can cause mucosal hemorrhaging and focal eosinophilia in the rhesus monkey, white mouse, and probably man (Overstreet and Meyer 1981). Also, the bacterium *Vibrio parahaemolyticus* and probably a few other microbial organisms can cause human disease if contaminated fish are eaten when inadequately prepared. High levels of toxic heavy metals and organic pollutants may cause human health problems, if both fish and consumer concentrate enough of the contaminant.

The parasites of seatrouts deserve considerably more attention than they have received. Many more species than listed in Table 20 probably occur. For example, the myxosporans *Sinuolinea dimorpha* (Davis 1916) in the urinary bladder and ureters and *Myxidium glutinosum* Davis 1917 in the gall bladder commonly occur in *C. regalis* in North Carolina (Davis 1917), and these or related species probably infect seatrouts in Mississippi. No critical examination of seatrouts for those or other protozoans was made, and, of those listed (Table 20), most are undescribed species. The microsporidian *Pleistophora* sp. in small cysts within the liver may be conspecific with the organism occurring also in Mississippi in *Bairdiella chrysoura* (Lacépède), *Micropogonias undulatus* (Linnaeus), *Pogonias cromis* (Linnaeus), *Sciaenops ocellatus* (Linnaeus), *Menticirrhus americanus* (Linnaeus), and *Leiostomus xanthurus* Lacépède. There may be more than one species in those sciaenids, and one or more of those species may appear morphologically different in different hosts.

Some helminths are definitely undescribed, such as the philometrid. The female of this species occurs encapsulated in the mouth. A few species, such as *Phyllodistomum* sp., were rare. That gorgoderid occurred in two fish, and the specimens did not have eggs fully enough developed to confirm whether the species was conspecific with *P. trinectes* Corkum 1961 which infects the sympatric *Trinectes macu-*

*latus* (Bloch and Schneider). Adults that correspond with the several listed immature forms need to be determined. Also, some species may be synonyms of others. Sinclair et al. (1972) and Stunkard (1980) considered *Stomachicola magna* as a junior synonym of *S. rubea*, a decision which needs confirmation. Also, whether *Cynoscionicola pseudo-heteracantha* (Hargis 1955) from *C. nothus* (possibly *C. arenarius*, see Hargis 1956) is a junior synonym of *C. heteracantha* needs to be established. Since monogeneans usually exhibit a great deal of host-specificity, this question would aid in better understanding the seatrout relationships.

A few abnormalities have been reported in the spotted seatrout. Most affected fish probably become prey before their schoolmates, not surviving long. Examples of anomalous fish include at least two fish with a pug-headed condition (Rose and Harris 1968, Hein and Shepard 1980) and one with lordosis (Burgess and Schwartz 1975). Fish occasionally also have unexplainable internal lesions (Figures 74–75). Perhaps such conditions and lesions develop from surviving an attack from a predator, from obtaining inadequate diets, from degenerating parasites, as well as from surviving congenital developments; most individuals of the cestode *P. caryophyllum* probably live in the seatrout at least 3 years before degenerating (Overstreet 1977). Some lesions are known to result from parasites (RTLA-1726, Smithsonian Institution). Neoplasms are not reported from *C. nebulosus*, but probably occur on occasion; a possible lipoma has been described from *C. regalis* (see Tubiash and Hendricks 1973), and a similar noninvasive one has been collected by John Couch (Environmental Protection Agency, personal communication) in the body cavity of *C. nebulosus* from Pensacola Bay, Florida.

Mortalities and life-threatening situations involving seatrouts in addition to those resulting from biological agents often result from environmental conditions. The spotted seatrout takes less time to equilibrate to unfavorable environmental conditions than some other fishes and exhibits considerable tolerance to some chemicals. Compared to *C. arenarius*, *C. nebulosus* has a higher metabolic rate at 15°C, and that rate does not increase when the fish is transferred from 25 to 30°C (Vetter 1977, 1982). On the other hand, large numbers of the seatrout die periodically from low temperature. Adkins et al. (1979) reported dead and stunned seatrout in Louisiana in January 1977 and February 1978, and Gunter (1952) reviewed numerous cases in Texas. Gunter (1941) estimated a 77.6% decline in fisheries catch of seatrout 3 months after a freeze. Moore (1976), working near Redfish Bay and Port Aransas, Texas, noted that both large and small *C. nebulosus* became moribund at temperatures of 4°C and had restricted swimming at 7°C. The latter, but not those at 4.0 and 4.5°C, could recover if warmed to 10°C over an 8 hr period. In Florida, Tabb (1958) noted that seatrout recover from being immobilized by cold for short periods, but do not recover from exposure to 7°C for 24 hr.

The rate of temperature reduction and salinity concentration probably both influence the tolerance of seatrout to low temperature (Overstreet 1974). When metabolic rates were tested at 28°C, the optimal salinity was about 20 ppt in South Texas (Wohlschlag and Wakeman 1978). Maximum sustained swimming speeds also occurred at 20 or 25 ppt (Wakeman and Wohlschlag 1977). If possible, the species usually moves into deep water or channels as harsh conditions develop (Guest and Gunter 1958, personal observations). The ability of *C. nebulosus* to control its metabolic rate within a narrower range in response to seasonal temperature changes than does *C. arenarius* and presumably *C. nothus* is probably a major factor in determining distribution of the three species (Vetter 1982).

Larvae of seatrout, just like those of most fishes, cannot withstand rapid temperature or salinity changes. When the temperature in Texas ponds increased from 25 to 34°C in 3.5 hr, apparently nearly all fish died (Colura et al. 1976). Another problem of high temperatures involves supersaturation of gases, especially nitrogen. Seatrout exposed to such conditions developed exophthalmia and died (Parker et al. 1978). Consequently, eliminating such conditions should be considered when power plants are designed so that they could accommodate aquaculture facilities. Also, most larvae died when dissolved oxygen in all but the top 15 cm of water in Texas ponds dropped below 4.0 ppm (Colura et al. 1976). Larvae failed to survive to metamorphosis at 23.5°C, but developed well at 28°C (Colura 1974). Higman (1967) noted a similarity in curves describing the annual catch rate of seatrout in the Everglades National Park and the annual rainfall that occurred three years previously. Even though that implied that rainfall influenced survival of larval and juvenile seatrout, he considered other environmental parameters of greater importance.

Toxic chemicals also influence survival. When Johnson et al. (1977) tested the tolerance of eggs and larvae to chlorine using a static test, they concluded that larval loss should be considerable in areas of chlorinated effluent disposal where toxic products of sodium hypochlorite occur above 0.17 ppm. Butler (1969) examined DDT in six generations of seatrout and noted variations in resistance of offspring to the pesticide, with that resistance being dependent on the stage of oocytes present when the female was exposed. In the Laguna Madre, Texas, where DDT residues were consistently high, reaching as high as 8 ppm in the gonads, seatrout apparently did not breed for at least one or two years (Butler 1969, Butler et al. 1970). The seatrout apparently acquired the pesticide primarily from eating juvenile menhaden, and levels in the menhaden reached a peak in February 1968 (Breuer 1970).

#### ACKNOWLEDGMENTS

I gratefully thank the following people from GCRL who aided considerably in different aspects of and at different periods of this study: Ronnie G. Palmer, Rena Krol, Joan Durfee, Kay Richards, John Lamb, Roswitha Buxton, Theresa Miller, Donald Bump, James Carter, Steve Shepard, Thomas Deardorff, Tom Mattis, John Fournie, Pat McKinney, John Cirino, Kenneth Melvin, Joanne Laroche, Lucia O'Toole, Jerima King, Valarie Hebert, Lois Coquet, and Helen Carroll. Several others also provided information and specimens. Among these are Martin Roessler of Tropical BioIndustries, Inc., Fayard's Ocean Springs Seafood, and Robert Colura of Texas Parks and Wildlife. The study was conducted in cooperation with the U.S. Department of Commerce, NOAA, National Marine Fisheries Service, under PL 88-309, Projects 2-325-R, 2-382-R, and 2-393-R.

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# Gulf Research Reports

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Volume 7

Issue 5 Volume 7, Supplement 1

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January 1983

Aspects of the Biology of the Red Drum, *Sciaenops ocellatus*, in Mississippi

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DOI: 10.18785/grr.07supp.02

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*SCIAENOPS OCELLATUS*, IN MISSISSIPPI

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**ABSTRACT** Several hundred specimens of the red drum from Mississippi were critically assessed. Regression equations for standard-length (SL) versus total-length differed between males and females and between small and large members of the same sex. A single regression line represented the weight-SL relationship for males with females. For condition coefficients to be helpful, fish had to be grouped at least by sex, season, and length or stage of maturity. By 12 months of age, most fish were about 30 to 32 cm SL and their distribution ranged throughout Mississippi Sound rather than being restricted to in-shore bayou and marsh habitats like younger individuals. Juvenile fish tended to have a high hepatosomatic index (HSI) in winter, and adults had a low one following spawning. The gonosomatic index (GSI) was typically lower than the HSI except for gravid fish in spring and summer. The number of oocytes available for spawning appeared to be much higher than cited in previous reports. The highest calculated fecundity, occurring in a 758 mm SL fish, was 62 million using a volumetric displacement method and 95 million using a gravimetric one. Extrapolated estimates for larger fish were much higher. Resting and yolk-vesicle stage oocytes typically had an irregular shape, an eccentrically located nucleus, and an abundance of highly basophilic substance in the ooplasm. Throughout a seasonal histological examination, both gonads contained, often in an abundance, Periodic-acid-Schiff-positive granular leukocytes. Spawning took place in late September and October one year, but apparently has occurred over longer periods when conditions of temperature and photoperiod were appropriate. No tagged, 1-year-old fish were returned from farther than 33 km from the point of release. Adults, however, apparently migrated extensively, especially from October through April. Those adults tagged several km south of the barrier islands included individuals caught 778 km away in Texas after 746 days and 316 km away in Florida after 399 days. Another fish apparently migrated at least 120 km in inshore waters in 6 days or fewer. An estimated 25 million kg or more of red drum occurred at one time between the Mississippi River and Mobile Point, Alabama. The red drum served as a host for a variety of parasites, some capable of having an adverse effect on natural stocks, on cultured stocks, and on seafood consumers, and most species known to infect the drum are listed in a table. The red drum has succumbed to some microbial agents, low dissolved oxygen concentration, rapidly dropping temperatures, and other detrimental conditions, some unidentified or unexplained. Probably, considerable mortality can be attributed periodically to environmental or environmentally-influenced conditions and to parasitic infections.

#### INTRODUCTION

The red drum, *Sciaenops ocellatus* (Linnaeus), has been a historically important food fish, but the recent introduction of small purse seines in the northern Gulf of Mexico increased its importance in supporting a commercial fishery in that region. The fish ranges and is fished commercially and recreationally from New York to the Gulf of Mexico coast of northern Mexico. Because numerous aspects of the biology of the red drum have been misinterpreted or are not known and because the life history of the fish in Mississippi has been sparsely documented (e.g., Eitzold and Christmas 1979), I undertook this study. Food contents have already been assessed (Overstreet and Heard 1978).

#### MATERIALS AND METHODS

The study was initiated in 1978 to run in conjunction with one involving the spotted seatrout, *Cynoscion nebulosus* (Cuvier), with the original intention to work aboard commercial purse seining vessels. In 1979, restrictions on commercial fishing halted that arrangement. Nevertheless, considerable data collected before and after 1979 have provided enough useful information to present. Methods includ-

ing those for the diagnosis of gonad states are the same as reported for the seatrout study in this same issue (Overstreet 1983) except that collections extended into November 1982. Unless otherwise indicated, all sectioned material was stained with Harris's hematoxylin and eosin Y, all fish-lengths are standard length (SL), and all material is from Mississippi.

#### RESULTS AND DISCUSSION

##### *Body Relationships and Growth*

Equations to predict total length (TL) from standard length (SL) and vice versa occur in Table 1. The logarithmic transformation of  $TL = aSL^b$ , or  $\log TL = \log a + b(\log SL)$ , produced the equation for all 861 fish as  $\log TL = 0.1262 + 0.9809(\log SL)$  with a correlation coefficient ( $r$ ) = 0.9978. Since both equations produced similar values and equations based on nontransformed data are easier to work with and routinely reported in the literature, nontransformed data will be assessed in detail below.

Because lengths of the red drum covered a wide range and large fish (colloquially known as bull reds in Mississippi) and small fish (rat reds) generally occupied two different habitats (Gulf of Mexico and the estuary including and associated with Mississippi Sound, respectively), the data were

TABLE 1.

Standard length-total length relationship for 861 individuals of *Sciaenops ocellatus* from Mississippi by sex and length group (N = number of fish examined; a = TL [or SL] axis-intercept; b = slope; and r = correlation coefficient).

Sex	Length group in mm	Standard length range in mm	N	TL = a + b (SL)				Calculated TL for a 350 mm SL fish	Calculated TL for a 550 mm SL fish
				a	b	95% confidence interval of b	r		
Unsexed		162-965	426	15.6378	1.1642	1.1540-1.1743	0.9959	423.1	656.0
Female	<550	164-540	92	27.4244	1.1091	1.0883-1.1300	0.9960	415.6	637.4
Male	<550	143-546	250	19.2152	1.1322	1.1179-1.1465	0.9949	415.5	642.0
Female	≥550	552-855	39	-16.0844	1.1859	1.1099-1.2619	0.9820	399.0	636.2
Male	≥550	550-857	54	-49.9480	1.2458	1.1712-1.3203	0.9776	386.1	635.2
Female	combined	164-855	131	16.0335	1.1385	1.1237-1.1534	0.9972	414.5	642.2
Male	combined	143-857	304	10.4411	1.1587	1.1492-1.1682	0.9974	416.0	647.7
Female and Male	combined	143-857	435	12.7971	1.1502	1.1424-1.1580	0.9974	415.4	645.4
All	combined	143-965	861	7.3032	1.1712	1.1657-1.1768	0.9975	417.2	651.5
SL = a + b (TL)									
Unsexed		162-965	426	-7.6619	0.8519	0.8445-0.8593	0.9959	419.8	654.6
Female	<550	164-540	92	-21.3661	0.8944	0.8776-0.9112	0.9960	415.2	638.8
Male	<550	143-546	250	-13.4498	0.8743	0.8633-0.8853	0.9949	415.7	644.5
Female	≥550	552-855	39	37.7042	0.8131	0.7610-0.8652	0.9820	384.1	630.1
Male	≥550	550-857	54	69.0953	0.7672	0.7213-0.8131	0.9776	366.1	626.8
Female	combined	164-855	131	-11.3153	0.8734	0.8621-0.8848	0.9972	413.7	642.7
Male	combined	143-857	304	-6.8981	0.8585	0.8515-0.8655	0.9974	415.7	648.7
Female and Male	combined	143-857	435	-8.8855	0.8649	0.8590-0.8708	0.9974	414.9	646.2
All	combined	143-965	861	-3.4416	0.8495	0.8455-0.8536	0.9975	416.1	651.5

separated into those for fish larger and for fish smaller than 550 mm SL. Because of variation in seasonal data influenced by yearly differences and small sample sizes, those data for all seasons are combined and the various pairs compared using analysis of covariance (ANOC). Even though variances were homogeneous for comparisons between large and small fish of the same sex and both large and small individuals of different sexes, the means did not differ ( $F = 0.04 - 2.45 < F_{0.05(1,90-339 \text{ df})} = \sim 3.95$ ), and one regression line could represent data for pairs between sexes ( $F = 1.71 - 1.84 < F_{0.05(2,89-338 \text{ df})} = \sim 3.10$ ) except those of the same sex less than 550 mm versus those greater than 550 mm ( $F = 12.78, 3.64 > F_{0.05(2,300-127 \text{ df})} = \sim 3.07$ ). The regression lines for those pairs, as well as those for when pairing all males versus all females which also could not be combined ( $F = 5.73$ ) and had different means ( $F = 6.16$ ), differed in their slopes ( $F = 25.52, 6.97, 5.24 > F_{0.05(1,300, 127, 431 \text{ df})} = 3.9$ ). The linear slopes ( $F = 1.64 < F_{0.05(1,1283 \text{ df})} = 3.85$ ), but not intercepts ( $F = 8.90 > F_{0.05(1,1284 \text{ df})} = 3.85$ ), were the same when comparing the regression line of unsexed fish with that for all fish combined. Other combinations did not have homogeneous variances.

Data are also compared by calculating from each equation

the TL of both a 350 and a 550 mm SL fish. Note the slight difference that occurs in the corresponding values (Table 1) depending on whether TL or SL serves as the dependent variable. On the other hand, note that when calculated TL is based on an equation derived from large fish, it is shorter for a 350 mm SL fish than when it is based on small fish or on all fish combined. It exemplifies the inaccuracy in extrapolating from inappropriate data. The highest calculated TL values came from the equations based on the unsexed category, a group including a large number of adult fish that had been measured, tagged, and released, as well as including some small immature individuals.

Values have been determined for fish from other areas, and they do not always correspond with those presented here because of deviations possibly resulting from size of fish, sex of fish, and environmental factors in different geographic regions. Also, seasonal differences probably influenced values as shown by Overstreet (1983) for *Cynoscion nebulosus*, also from Mississippi. Hein et al. (1980) determined  $SL = -2.0520 + 0.8369 TL$  with  $r = 0.9996$  based on 302 fish from Louisiana, 14 to 1135 mm TL; Jorgenson and Miller (1968) determined  $SL = -0.290 + 0.799 TL$  based on 5 fish from Georgia, 13 to 32 mm SL; Harrington et al.

(1979) determined  $TL = 12.870 + 1.177 SL$  with  $r = 0.995$  based on 8982 fish, 67 to 785 mm SL; Luebke and Strawn (1973) determined  $TL = 24.069 + 1.141 SL$  for 40 fish averaging about 33 cm SL in Texas.

The relationship between SL and weight is indicated in Table 2 and Figure 1. The fitted equations for  $\log W = \log a + b (\log SL)$  and the reverse using SL as the dependent variable indicate the need in some cases to depend heavily on the length of fish used to derive the equation. Note especially the calculated weights for 350 mm fish based on equations derived from large fish.

Regression equations had a serious drawback in spite of their high correlation coefficients; that drawback was the lack of homogeneous variances when comparing by ANOC several of the different combinations listed in Table 2; specifically, calculated differences in slopes between large and small individuals of the same sex were not based on data meeting the required criteria. Comparisons of large females versus males and small females versus males had homogeneous variances, but for the large pair, the means did not differ ( $F = 0.46 < F_{0.05(1,74 \text{ df})} = 3.97$ ), and one regression line could suffice for all the data ( $F = 0.35 < F_{0.05(2,73 \text{ df})} = 3.12$ ). For the small pair, the means differed ( $F = 12.30 >$

$F_{0.05(1,338 \text{ df})} = 3.87$ ), one regression line could not be used for all the data ( $F = 6.48 > F_{0.05(2,337 \text{ df})} = 3.03$ ), the linear ( $F = 0.01$ ) slopes did not differ ( $F = 0.68$ ), but their intercepts did differ ( $F = 12.29 > F_{0.05(1,338)} = 3.87$ ). There were no statistically significant differences when data for unsexed specimens were added to those for the combined males and females or when those for females (also for males, but the involved variances for those were not homogeneous) were compared with all data combined. Consequently, Figure 1 represents a general approximation of the weight-SL relationship for red drum in Mississippi that can be used, but with caution, especially regarding possible seasonal differences.

Weight-standard length regression equations have been determined for fish from areas other than Mississippi that should also be used with caution: Louisiana - 286 fish, 250 to 932 mm SL,  $\log W = -4.42161 + 2.83234 (\log SL_{mm})$  (Boothby and Avault 1971); 568 fish, 8 to 183 mm SL,  $\log W = -7.2052 + 4.1913 (\log SL_{mm})$  (Bass and Avault 1975); 302 fish, 14 to 1135 mm TL,  $\log W = -5.1197 + 3.0523 (\log TL_{mm})$  (Hein et al. 1980); Texas - 8319 fish, 71 to 970 mm TL,  $\log W = -5.085 + 3.041 (\log TL_{mm})$  (Harrington et al. 1979); a graph by Pearson (1929, Fig. 12),

TABLE 2.

Standard length-weight relationship for 480 individuals of *Sciaenops ocellatus* from Mississippi by sex and length group (N = number of fish examined; Log a = Log W [or Log SL] axis intercept; b = slope; and r = correlation coefficient).

Sex	Length group in mm	Standard length range in mm	N	Log W = Log a + b (Log SL)				Calculated weight for a 350 mm SL fish in g	Calculated weight for a 550 mm SL fish in g
				Log a	b	95% confidence interval of b	r		
Unsexed		162-965	62	-4.5318	2.9316	2.8394-3.0239	0.9927	844.1	3175.7
Female	<550	164-540	91	-4.5988	2.9559	2.8709-3.0408	0.9908	834.1	3172.8
Male	<550	143-546	250	-4.7125	2.9935	2.9475-3.0395	0.9925	800.3	3095.8
Female	≥550	552-855	37	-6.3930	3.5896	3.1715-4.0078	0.9469	548.5	2778.5
Male	≥550	550-857	40	-6.0026	3.4553	3.1065-3.8040	0.9559	613.6	2925.3
Female	combined	164-855	128	-4.6937	2.9920	2.9260-3.0579	0.9923	828.2	3202.3
Male	combined	143-857	290	-4.7956	3.0268	2.9932-3.0603	0.9955	803.1	3154.5
Female and Male	combined	143-857	418	-4.7902	3.0258	2.9965-3.0551	0.9950	808.4	3173.9
All	combined	143-965	480	-4.7358	3.0053	2.9766-3.0340	0.9944	812.6	3160.9
Log SL = Log a + b (Log W)									
Unsexed		162-965	62	1.5618	0.3361	0.3255-0.3467	0.9927	836.7	3210.6
Female	<550	164-540	91	1.5746	0.3321	0.3226-0.3417	0.9908	830.2	3238.0
Male	<550	143-546	250	1.5882	0.3291	0.3240-0.3341	0.9925	802.6	3169.2
Female	≥550	552-855	37	1.8901	0.2498	0.2207-0.2789	0.9469	414.9	2533.8
Male	≥550	550-857	40	1.8309	0.2644	0.2377-0.2911	0.9559	498.1	2752.5
Female	combined	164-855	128	1.5856	0.3291	0.3218-0.3363	0.9923	817.3	3227.4
Male	combined	143-857	290	1.5932	0.3274	0.3238-0.3310	0.9955	802.2	3190.5
Female and Male	combined	143-857	418	1.5932	0.3272	0.3240-0.3304	0.9950	805.5	3206.3
All	combined	143-965	480	1.5872	0.3290	0.3259-0.3322	0.9944	809.9	3199.3

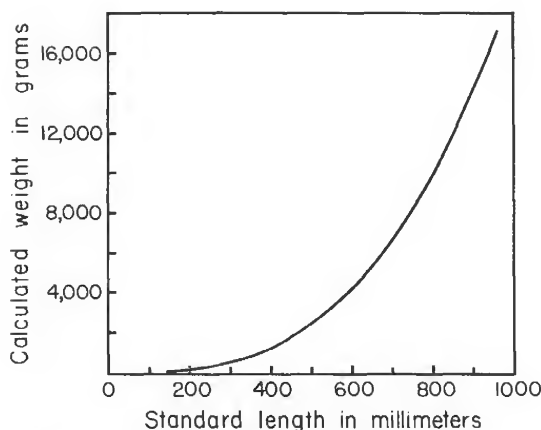


Figure 1. Standard length-weight relationship based on the equation  $\text{Log } W = -4.7358 + 3.0053 (\text{Log } SL)$ .

47 fish, 283 to 411 mm in pond,  $\text{Log } W = -4.69 + 2.97 (\text{Log } SL_{mm})$  (Luebke from Perret et al. 1980); and South Carolina — 88 fish in a marsh impoundment,  $\text{Log } W = -1.29596 + 2.74031 (\text{Log } SL_{cm})$  (Theiling and Loyacano 1976).

Because of some of the problems involved with the above regression equations and with size of fish in different length-groups, the condition coefficient,

$$K = \frac{W \times 10^5}{SL^3},$$

is presented for both males and females as well as seasonally for different length groups (Table 3). Comparative values also occur for fish in different stages of maturity (Table 4). Because of small sample sizes, data from different months and years were grouped by season. Both males and females larger than 700 and in stage IV and V during spring and summer tended to have relatively high K values. High ones for two females were 2.83 and 2.67 and for two males 2.73 and 2.67. The K does not necessarily increase with fish length or stage of maturity. On the other hand, "stage of maturity" is misdiagnosed in a few cases because the stages are based on appearance of maturing spotted seatrout (Overstreet 1983), and many more adult seatrout than adult red drum were examined. A few specific cases are pointed out in a later section on histology. With additional data, stages should be more precise and K tables should be more helpful. Nevertheless, a single or average K value representing a species of fish, regardless of sex, length, or season, can be misleading (e.g., by the commercial Richie Fish Computer [Professional Model],  $K_{TL} = 1.22$ ).

By calculating K identically to that described here, Boothby and Avault (1971) calculated for adult fish in "good condition" as K = 1.3 (1.2–1.6) in winter, 1.4 (1.2–1.6) in spring, 1.4 (1.2–1.6) in summer, and 1.5 (1.2–1.7)

in autumn. Luebke and Strawn (1973) calculated K for fish in two ponds receiving heated discharge water from a power plant and noted monthly values from 1.67 to 1.94 from June through November. Those latter values, higher than ones determined from adults in Louisiana, but lower than those for 568 juveniles in Louisiana ( $K = 1.773$  to  $2.077$ ,  $\bar{x} = 1.969$  by Bass and Avault 1975), are somewhat less than some reported here, but variation existed, even among summer values for fish from Mississippi. To obtain the most value from condition coefficients, a continuum of comparative samples should be related (e.g., Ellis and Gowing 1957, Colle and Shireman 1980, Overstreet 1983).

The red drum grew rapidly, but inconsistently, in Mississippi. Over a 3-year period, Loman (1978) collected several 6 to 9 mm SL postlarvae in grassy or muddy shallow water habitats in Mississippi Sound. These fish were limited to September, October, or November and collected by a beam net only. As small juveniles, the fish occurred in marsh habitats, moving into bayous and canals from at least November through early summer. Consequently, these and other young specimens seldom occurred in trawls or beach seines unless captured from a channel during a cold period. Several fingerlings have been collected and many more seen, but their measurements are not included in the tables. They were seined from mouths of or short distances up bayous or from depressions in marshy areas where they stranded following especially high receding tides. A range of length from 4 to 8 cm SL for fish in January suggests variation in growth or differences in spawning dates.

Generalized growth of juveniles after about 7 months, assuming a spawn about September, can be followed by length-frequency data in Table 5. Because of the paucity of available fish, those individuals from all years using all methods of collection are pooled. Year-old fish averaged about 30 to 32 cm SL. The shorter fish were collected from bayous and Back Bay of Biloxi only. By mid-August, some relatively short fish came from off Deer Island and Round Island, islands occurring within Mississippi Sound, but not barrier islands delimiting the Gulf of Mexico. By September, some came from near the barrier islands as well as from the inshore marsh habitats.

Bass and Avault (1975) made nine collections at Grand Isle, Louisiana, from 30 October to 23 May. During that period the mean SL of the red drum increased from 15.7 to 145.0 mm for an average monthly growth of 18.8 mm for the first 7½ months of life (20.4 mm when considering largest individuals per sample). Simmons and Breuer (1962) reported a growth rate of from 19.2 to 34.2 mm per month for fish in their first year in the Upper Laguna Madre, Texas, where sporadic growth with a spring lag occurred. At Eighth Pass, Mexico, Miles (in Simmons and Breuer 1962) noted fish 200 mm TL in July, or 50 to 60 mm TL less than the fish observed in the Upper Laguna Madre by Simmons and Breuer. Based on tagging, Simmons and Breuer (1962)

TABLE 3.  
Seasonal condition coefficient (K [standard length]) and hepatosomatic index (HSI) of *Sciaenops ocellatus* collected from 1972 to 1982 relative to sex and length of fish.

Standard length in millimeters																			
<300				300-549				550-699				700-849				> 850			
Sample size		K±SE	HSI±SE	Sample size		K±SE	HSI±SE	Sample size		K±SE	HSI±SE	Sample size		K±SE	HSI±SE	Sample size		K±SE	HSI±SE
Autumn																			
Female		10	1.90±0.11	1.28±0.18	22	1.92±0.05	1.36±0.12	6	1.74±0.16	1.00±0.09	3	1.82±0.13	1.03±0.09	0			0		
Male		23	1.91±0.05	1.60±0.18	61	1.90±0.02	1.50±0.06	11	1.88±0.05	0.93±0.08	4	1.56±0.04	1.03±0.11	0			0		
Winter																			
Female		1	2.24	1.94	33	1.93±0.03	1.88±0.08	9	1.78±0.10	1.25±0.20	0			0			0		
Male		1	2.07	2.62	49	1.83±0.02	1.33±0.05	4	1.75±0.08	1.00±0.22	1	1.93	1.58	0			0		
Spring																			
Female		1	1.78	0.61	15	1.94±0.06	1.11±0.05	2	1.69±0.17	0.96±0.11	13	2.21±0.10	1.71±0.14	1	1.96	1.39	1	1.96	1.39
Male		1	1.79	1.34	56	1.89±0.02	1.07±0.04	7	1.81±0.05	1.07±0.13	11	2.28±0.10	1.84±0.10	0			0		
Summer																			
Female		5	1.90±0.05	1.09±0.15	8	2.00±0.13	1.03±0.12	2	1.78±0.00	1.24±0.72	1	1.91	2.44	0			0		
Male		56	1.84±0.02	0.91±0.03	10	1.82±0.03	1.02±0.06	1	1.95	0.91	1	1.88	1.92	0			0		

TABLE 4.

Seasonal condition coefficient (K [standard length]), hepatosomatic index (HSI) and gonosomatic index (GSI) of *Sciaenops ocellatus* in Mississippi relative to stage of maturity of fish.

Sample size	Stage of Maturity	Autumn		Winter		Spring		Summer	
		Female	Male	Female	Male	Female	Male	Female	Male
Sample size	I	12	38	24	0	5	16	6	51 <sup>1</sup>
	K±SE	1.87±0.09	1.94±0.03	1.95±0.04		1.83±0.04	1.83±0.04	1.92±0.04	1.83±0.02
	HSI±SE	1.27±0.11	1.54±0.10	1.97±0.06		1.00±0.12	1.06±0.06	1.14±0.13	0.92±0.02
	GSI±SE	0.03±0.01	0.02±0.00	0.03±0.00		0.04±0.02	0.03±0.01	0.02±0.01	0.02±0.00
Sample size	II	16	42 <sup>2</sup>	8	49	11	38	5	13
	K±SE	1.94±0.08	1.85±0.03	1.82±0.04	1.82±0.02	1.97±0.07	1.91±0.03	1.80±0.12	1.86±0.04
	HSI±SE	1.52±0.14	1.51±0.09	1.60±0.27	1.32±0.06	1.12±0.07	1.13±0.04	1.00±0.11	0.94±0.08
	GSI±SE	0.14±0.06	0.05±0.01	0.05±0.01	0.02±0.00	0.04±0.01	0.03±0.00	0.06±0.01	0.15±0.12
Sample size	III	11	7	9	4	3	11	0	3
	K±SE	1.81±0.04	1.85±0.08	1.90±0.08	1.89±0.05	1.72±0.09	1.84±0.02		1.88±0.05
	HSI±SE	0.99±0.16	1.30±0.21	1.52±0.20	1.73±0.19	1.17±0.26	0.94±0.13		0.98±0.10
	GSI±SE	0.48±0.10	0.07±0.02	0.18±0.02	0.12±0.09	0.34±0.18	0.12±0.05		0.12±0.09
Sample size	IV	2	9	2	1	13	10	2	0
	K±SE	1.93±0.15	1.96±0.07	1.78±0.61	1.94	2.22±0.09	2.32±0.10	2.42±0.30	
	HSI±SE	0.88±0.11	0.94±0.09	0.81±0.18	0.74	1.69±0.15	1.87±0.11		
	GSI±SE	0.57±0.31	0.30±0.07	0.21±0.00	0.06	0.67±0.04	0.32±0.01		
Sample size	V (and VII)	0	3	1	0	0	0	3	1
	K±SE		1.57±0.06	2.18				1.82±0.06	1.88
	HSI±SE		1.03±0.17	0.45				1.64±0.61	1.92
	GSI±SE		0.86±0.09	0.59				1.94±1.23	2.42

<sup>1</sup> Sample size for GSI was 49. <sup>2</sup> Sample size for HSI was 41 and that for GSI was 39.

TABLE 5.

Monthly length-frequencies of 484 juvenile *Sciaenops ocellatus* between 100 and 400 mm SL in Mississippi. The short individuals in May can be assumed to be about 7 months old.

Month	Length group in mm SL										No. of fish
	100-129	130-159	160-189	190-219	220-249	250-279	280-309	310-339	340-369	370-399	
May	2	1	1					7	4	2	17
June				2	2		1	2	2	2	11
July			4	5	5				1		15
August				3	76	24	11	2	1		117
September				1	1	9	15	3		1	30
October					2	10	47	26	4		89
November						3	7	14	2		26
December					1	7	7	14	17	6	52
January	2						13	31	3	2	51
February											
March						2	2	12	6	4	26
April						1		9	16	24	50
No. of fish	4	1	5	11	87	56	103	120	56	41	484

showed fish to average 325 mm TL at the end of the first year, 540 mm at the second, and 760 mm at the third, which are larger values than most authors report. Etzold and Christmas (1979) listed 34.0, 54.0, 64.0, 75.0, and 84.0 cm SL for fish through the fifth year, but these values probably are mean TL measurements presented by Pearson (1929). Arnold et al. (1977) reared 44 mm TL fingerlings to 250 mm (190 g) in 6 months and to 523 mm (1840 g) in 19 months.

#### Liver and Gonad Weights

Liver weight, expressed as the hepatosomatic index,

$$\text{HSI} = \frac{\text{Liver weight} \times 100}{\text{Total fish weight}},$$

is summarized in Tables 3 and 4. In the first table, the index, calculated seasonally and by sex, occurs relative to fish-length. In the second, the index occurs relative to the fish's stage of maturity. In some groups, the average index had considerable variation, enough to question sexual differences. In general, no relationship existed between HSI and fish-length. A tendency, however, was apparent for a high index in fish during winter for individuals in stages I to III and during spring and summer for the more mature large fish. The index was relatively low following spawning season in adults.

The gonosomatic index,

$$\text{GSI} = \frac{\text{Weight of gonads} \times 100}{\text{Total weight of fish}},$$

except for the large stage V (gravid, but not ready to spawn) individuals in summer, was lower than the HSI (Tables 4 and 6). The highest values were 3.9 for a female and 2.4 for a male. Presumably, the value for a spawning female would be much higher. Females tend to have higher values than

males in corresponding groups. The relationship between stage of maturity and fish-length is portrayed in Table 7.

#### Fecundity

The red drum is capable of producing a considerable number of oocytes. A linear relationship existed between SL and the logarithm of the number of oocytes over 16 to 30  $\mu\text{m}$  for 22 fish 294 to 800 mm SL (Figure 2). The maximum calculated estimated number of oocytes from a 758 mm SL female in March was 61,998,776, or 94,513,172 when calculated using the gravimetric rather than the volumetric displacement method. The gravimetric method produced values 0.67 to 3.14 (avg. 1.69) times greater than the displacement method. The number of oocytes in the only gravid fish and the only calculation based on fixed material was nearly 16 million (Table 8) or 24,425,025 when based on weight. The number would have been higher had a piece of ovary not been removed and an adequate fresh aliquot fixed so that more small oocytes could be distinguished (Figure 3). If the relationship shown in Figure 2 continues to hold as fish-length increases, a large 953 mm SL fish (the largest tagged, but several longer ones were observed) could theoretically produce 290 million oocytes over 16  $\mu\text{m}$  (or possibly 1.7 times that value using the gravimetric method). In any event, if spawned, the eggs from a single large red drum could supply more individuals than a reasonable total estimated number of living red drum over 300 mm. Of course, not all eggs hatch, and of those that do, relatively few resulting fish reach the juvenile stage and even fewer become adults. Overstreet (1983), in a paper on spotted seatrout, discussed the difference between the estimated numbers of seatrout oocytes using the volumetric and gravimetric methods as well as errors involved in those estimates using the same procedures. Table 8 shows an increase in

TABLE 6.  
Gonosomatic index (GSI) of *Sciaenops ocellatus* relative to length of fish.

	Standard length in millimeters									
	< 300		300-549		550-699		700-849		> 850	
	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE	Sample size	GSI±SE
Autumn										
Female	11	0.18±0.09	22	0.11±0.04	6	0.39±0.13	3	0.87±0.06	0	
Male	21	0.05±0.02	60	0.03±0.00	11	0.20±0.04	4	0.84±0.07	0	
Winter										
Female	1	0.01	33	0.05±0.01	9	0.17±0.03	0		0	
Male	1	0.03	49	0.02±0.00	4	0.05±0.01	1	0.36	0	
Spring										
Female	1	0.00	15	0.42±0.01	2	0.19±0.07	13	0.66±0.03	1	0.77
Male	1	0.00	56	0.04±0.01	7	0.06±0.02	11	0.31±0.01	0	
Summer										
Female	5	0.01±0.01	6	0.06±0.01	2	0.95±0.35	1	3.94	0	
Male	53	0.05±0.03	10	0.03±0.00	1	0.05	1	2.42	0	

TABLE 7.  
Relationship between length of *Sciaenops ocellatus* and stage of maturity<sup>1</sup> for a total of 482 males (M) and females (F).

Stage of Development	Standard length in millimeters										Grand Total
	< 300		300-549		550-699		> 700		Total		
	M	F	M	F	M	F	M	F	M	F	
I	83	18	40	33	2	2	—	—	125	53	178
II	15	3	127	37	3	5	—	—	145	45	190
III	2	2	11	8	11	15	3	9	27	34	61
IV	—	—	2	2	8	3	12	14	22	19	41
V	—	—	—	—	—	5	4	3	4	8	12

<sup>1</sup> Diagnosed on basis of gross observations of spotted seatrout gonads (Overstreet 1983) and a few cases do not agree histologically.

mean number of oocytes by stage of maturity through developing IV fish using the conservative volumetric displacement method. This number also increased by stage of fish maturation when calculated as number per gram of fish. On the other hand, because of an increase in diameter of oocyte with stage of maturity, the number tended to decrease when assessed as number per gram of ovary.

Oocyte diameters increase with stage of maturity as mentioned above and shown in Figure 3. The graph includes only a single gravid individual with its much larger oocytes. Roberts, Harpster, and Henderson (1978) measured oocyte diameters during conditioning for spawning under different conditions, but not immediately preceding spawning. Holt, Johnson et al. (1981) reported spawned eggs as 0.93 mm (0.86 to 0.98 mm) in diameter. They estimated fecundity values as one half to two million eggs per season for a 3- to 5-year-old female. Higher values have been reported: 2.5 million for a 825 mm TL fish (Miles 1951) and about 3.5

million for a 90 cm TL fish (Pearson 1929). In any event, the number is actually much higher than those estimates as shown by spawned eggs. A single female (6.2 kg or less) produced 2,058,000 eggs in one of several controlled spawns; of those, 95% hatched (Roberts, Harpster, and Henderson 1978). Arnold et al. (1977) estimated a total of 60 million fertilized eggs produced by three relatively small individuals over a 76-day period.

#### Histology of gonads

Sections of many, but not all, stages in the development of the gametes provide a helpful view of maturation of this fish in the northern Gulf of Mexico.

In the ovary, numerous oocytes occurred within lamellar folds (Figures 4-5); most had a characteristically irregular shape and an eccentric nucleus. In those ovaries examined during winter and spring, the ooplasm appeared mottled in stained preparations. Usually the peripheral zone and an



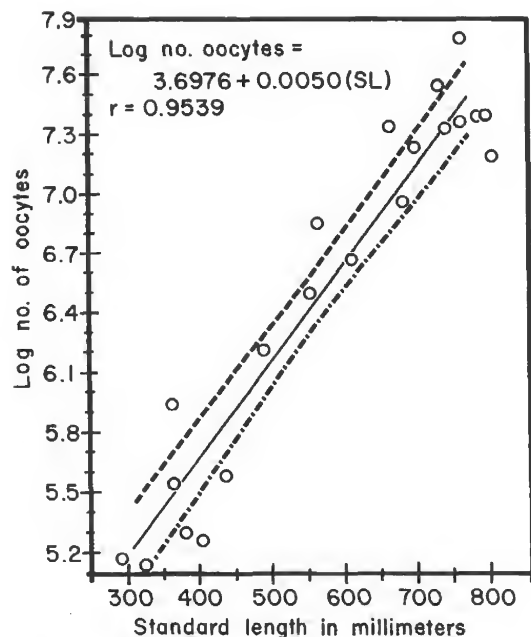


Figure 2. The logarithm of the number of oocytes estimated by volumetric displacement as a function of fish length. Only oocytes 16 to 30  $\mu\text{m}$  and larger are included.

irregular zone adjacent to the nucleus stained more basophilic than that zone in between (Figures 6–8). Also during winter and early spring, the tunica albuginea surrounding the ovaries reached its thickest measurement.

Figure 9 shows oocytes in two stages of vitellogenesis, as well as primary oocytes which occurred throughout the year. Vitellogenesis, as determined by stained yolk globules, occurred in oocytes as small as 70  $\mu\text{m}$  in diameter, but was typically more apparent in those well over 100  $\mu\text{m}$  and in those larger than concurrent oocytes in the preceding yolk-vesicle stage. As oocytes in the yolk-globule stage ripen in

late August and September, the osmophilic yolk vesicles (using osmium tetroxide method for fat-paraffin sections, in Luna 1968) coalesced to ultimately form a single lipid droplet; the purplish-stained yolk globules (in hematoxylin and eosin stain) gradually coalesced into moderately large spheres before fusing together and losing much of their color staining properties; and the nucleus appeared to migrate toward the cell's periphery and lose its irregular membrane (Figure 10). Nearly ripe, slightly misshapen, nonhydrated oocytes in late yolk-globule stage measured as long as 580  $\mu\text{m}$ .

Spent ovaries occurred in fish during early and late October (Figure 11). In addition to containing spent follicles, the ovary during that time had numerous atretic oocytes (Figures 11–12). Granular leukocytes functioned partially in encapsulating atretic oocytes (Figures 13–14). These cells with Periodic acid-Schiff (PAS)-positive granules occurred abundantly among connective tissue of both ovary and testis, being most numerous in spent individuals (e.g., Figure 15).

An enlargement of the hyaline portion of the zona pellucida occurred in oocytes from the central portion of one gravid ovary and probably represents an atypical condition (Figures 16–18). Some oocytes with such an investment had entered a state of atresia, and a bacterium had invaded a few of the oocytes within a focal area (Figures 19–20).

When examined on a seasonal basis, the testes exhibited a dynamic pattern in development related to age and season. In young males, spermatogenesis occurred more abundantly near the periphery than centrally and more abundantly near the midtestis than near the ends. The degree of those processes could not be differentiated in most more-developed fish. Testes of two first-year fish diagnosed as virgin had spermatozoa present in peripheral tubule lumens (Figure 21). Gravid males in August revealed an active state of spermatogenesis (Figure 22), and many live males during this period released milt when handled. Compact tubules were composed of numerous individual germinal cysts separated by Sertoli cells and bound together by a basement membrane

TABLE 8.  
Average fecundity of oocytes larger than about 16  $\mu\text{m}$  in *Sciaenops ocellatus* from Mississippi determined by volumetric displacement method in relation to stage of development.

Stage	N	Calculated mean no. oocytes $\pm$ SE	Mean wt of fish in g $\pm$ SE	Mean no. oocytes/g fish $\pm$ SE	Mean ovarian wt in mg $\pm$ SE	Mean no. oocytes/g ovary $\pm$ SE
Virgin	3	226,183 $\pm$ 81,938	939.3 $\pm$ 308.8	244 $\pm$ 36	0.27 $\pm$ 0.12	908,202 $\pm$ 174,767
Maturing Virgin	5	659,054 $\pm$ 282,240	1,230.8 $\pm$ 197.4	498 $\pm$ 163	0.54 $\pm$ 0.26	1,466,090 $\pm$ 531,533
Developing III	6	10,291,489 $\pm$ 3,118,787	4,435.4 $\pm$ 509.9	2,153 $\pm$ 469	18.46 $\pm$ 7.42	800,584 $\pm$ 233,437
Developing IV	7	29,002,812 $\pm$ 6,230,008	9,108.0 $\pm$ 687.6	3,198 $\pm$ 667	54.79 $\pm$ 6.50	505,853 $\pm$ 54,111
Gravid <sup>1</sup>	1	15,775,570	9,776.7	1,614	364.55	43,274

<sup>1</sup>Based on fixed material with small portion missing.

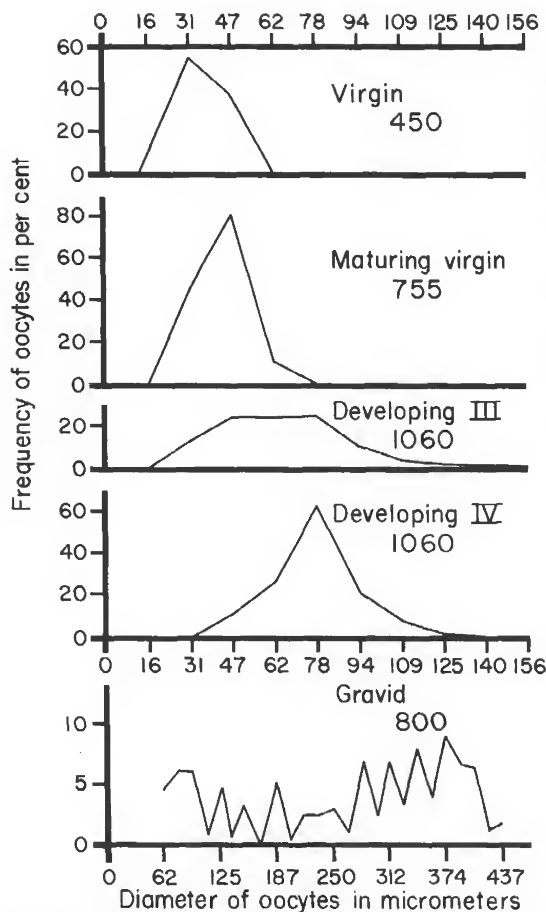


Figure 3. Length-frequency in percent of diameter of oocytes from fish in different stages of maturity.

and associated boundary cells. Within each cyst, synchronous development of the various stages was easily distinguished (Figures 23–27).

Testes of post-spawning fish in October retained an abundance of residual spermatozoa (Figures 28–30). Components of intralamellar septa increased in amount (e.g., Figure 31). Spent testes not undergoing extensive spermiogenesis occasionally exhibited foci of inflammatory reactions (Figure 32).

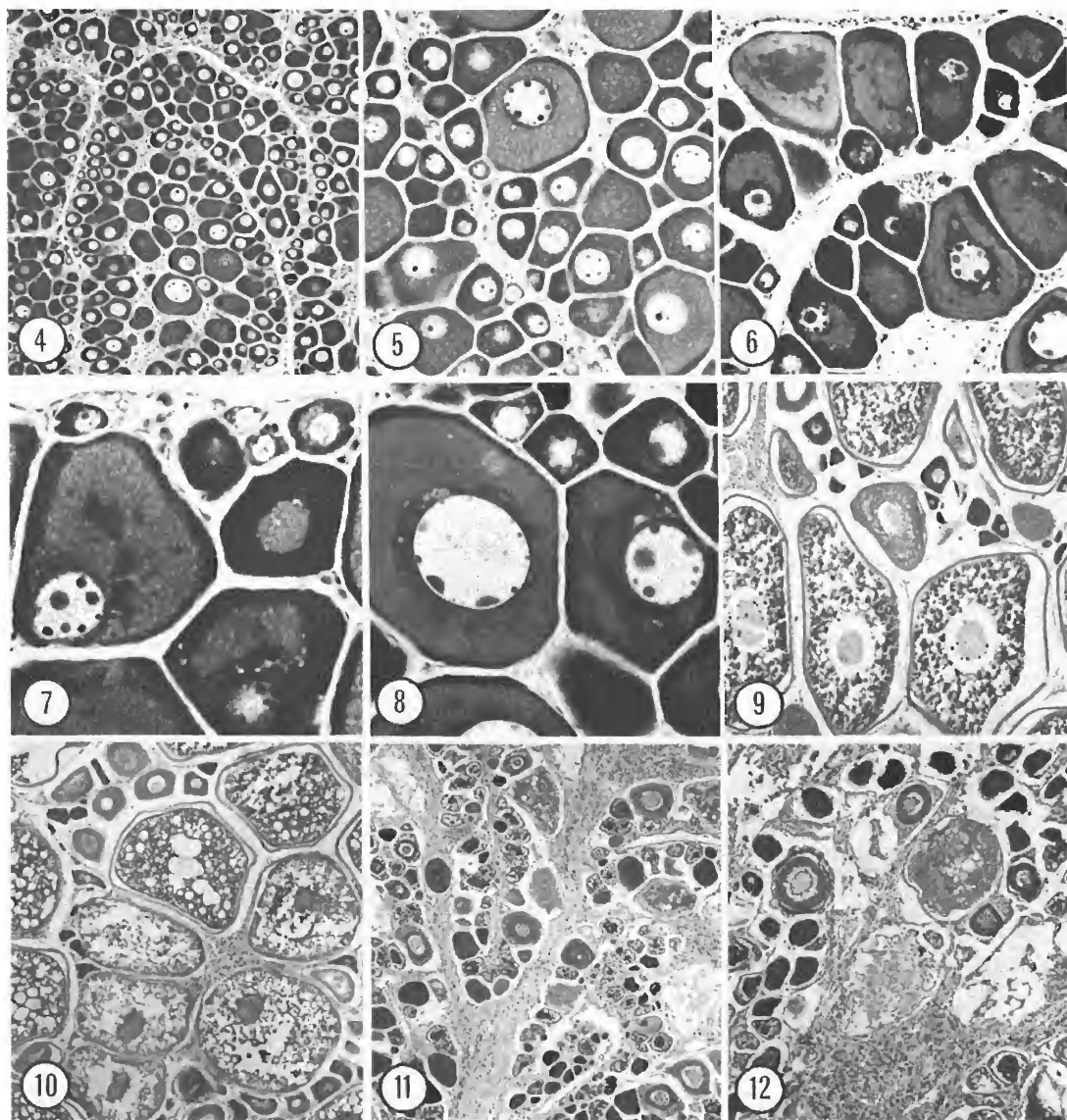
The red drum oocyte needs to be prepared for rapid lipogenesis and vitellogenesis so that it can produce a large number of eggs over a relatively short period. The large amounts of highly basophilic material may be the means. Even present in small oocytes, the material may be similar to that referred to as the pallial substance of Balbiani's vitelline body (Beams and Kessel 1973, Guraya 1979). It or portions have been implicated as an essential precursor substance necessary for oocyte growth and vitellogenesis. Perhaps an

ultrastructural study on the oocytes by D. E. Roberts, Jr., and developmental studies on the gonads in progress by Ruth Reese (Roberts, personal communication) will help solve this. The abundance of basophilic substance in the ooplasm, the eccentric nucleus, and the irregular shape constitute some of the differences between oocytes of the red drum and related spotted seatrout (Overstreet 1983). Another conspicuous difference between gonads of those two fish is the abundance of PAS-positive granular leukocytes in the red drum. This cell appears similar to that investigated by Barber and Westermann (1975, 1978). Several different leukocytes exist among different fish species, some referred to as eosinophils, but many of their various functions remain mostly unsolved (Hawkins et al. 1981). The PAS-positive granular cell in the drum at least associates with atretic oocytes. Stott et al. (1980) studied the testes of several fishes exposed to petroleum and mentioned that acidophilic cells, apparently similar to the one mentioned above in the drum, occurred in 50% of the testes. They were not clear about which species of fish contained such a cell, but they figured a focus in *Archosargus probatocephalus* (Walbaum).

#### Spawning

Actual spawning has not been observed in natural settings, possibly because it seems to occur near dusk (Arnold et al. 1977, Roberts, Harpster, and Henderson 1978). Most circumstantial data pertain to that collected in 1979. While aboard a commercial purse seiner several kilometers south of Horn Island on 24 August 1979, I noted one out of every nine handled large fish was a male that spewed milt. In spite of holding down large females to measure and tag them, none of them or any of the thousands of relatively smaller fish placed in the hold released ova. The two females returned to the laboratory were gravid and probably represented the average developmental stage of females in the stock. The catch included mostly 7 kg fish, but also included several 25 to 30 kg presumed females as well as others as small as 4.5 kg. Commercial fishing shortly after that period was suspended, and, soon before Hurricane Frederic on 12 September, schools disappeared, apparently migrating offshore to spawn. On 5 October, six confirmed spent females occurred among an especially large commercial catch of black drum. Thomas Fraser (Environmental Quality Laboratory, personal communication) has observed spent fish in Boca Grande, Florida, during the end of October.

The date and length of spawning almost certainly vary according to temperature, photoperiod, and possibly other factors. Pearson (1929) collected postlarvae near Texas passes from 11 October to 15 November 1926 and observed spent females in mid-November. King (1971) collected postlarvae from 13 August to 29 October 1968 with a peak in the second week in October and a shorter period from the last of September through October in 1969. Spawning even occurs off Chesapeake Bay in September to November as



Figures 4–12. Sectioned ovarian tissue from *Sciaenops ocellatus*. 4. Oocytes in lamellar folds of “maturing virgin” female in September at a time when adult fish had nearly ripe oocytes. 5. Close-up of ovary in Figure 4 illustrating primary oocytes and their typical irregular-shape. These later stage oocytes are undergoing early stage of lipogenesis, as shown by minute yolk vesicles in ooplasm. 6. Ovary designated as “developing IV” in December, with typical nutmeg-appearing mottled ooplasm and eccentric nuclei. The innermost, compact, basophilic zone surrounding the nucleus as well as the peripheral zone is probably the pallial substance of Balbiani’s vitelline body. Note the rather large, spherical nucleoli located near the periphery of the nucleus. Also note the cluster of young “chromatin nucleolus stage” oocytes located centrally along the lamellar margin. 7. Close-up of various-sized oocytes in same ovary as Figure 6 showing initial lipogenesis in oocytes with moderately basophilic ooplasm. 8. Close-up of oocytes in developing IV fish in March for comparison with oocytes in Figure 7. Note the prominent chromosomes, the more apparent activity associated with the pallial substance of Balbiani’s vitelline body with included yolk vesicles and spongy fat vesicles, and the more dense peripheral zone in the largest oocyte. 9. Oocytes in various stages in a gravid fish in August. Note the medium-sized oocytes undergoing vitellogenesis, the large oocytes with fat vesicles surrounding the nucleus, and small

shown by 20 to 90 mm TL fish entering the Bay (Mansueti 1960). Other authors indicate presumed spawning from September through February. Loiman (1978) reported postlarvae in inshore nursery grounds in Mississippi beginning in October of 1974 and September of 1975 and 1976. In 1975, postlarvae appeared until November. Offshore neuston samples showed some larvae in September 1974 and August 1976. On 8 and 9 October 1980, Wayne Laroche (Joanne Laroche, personal communication) dipped 9 mm SL postlarvae from a retaining wall at Point Cadet, Biloxi. Colura (1974), Arnold et al. (1977) and Roberts, Harpster, and Henderson (1978) have all successfully spawned red drum in culture systems. Without using gonadotropin injections, spawning could be induced by manipulating temperature and photoperiod combinations to simulate optimal conditions or seasonal variations (Roberts, Harpster, and Henderson 1978). Basically temperature was increased, sometimes to 29 or 30°C or so, the fish was triggered to spawn at 21 to 25°C, and the temperature was subsequently dropped to 21°C while the period of light that had been increased to 16 hr was dropped to 10 hr 15 min. By maintaining the temperature constant at about 23 to 24°C and light constant for 10 hr 15 min per day, spawning continued for up to 100 days. The number of these floating eggs per spawn typically dropped off from about one million per spawn for several spawns during the first 45 days to from ten to a hundred thousand thereafter. The maximal spawn on one night was 2,058,000 eggs per fish. One closely examined fish spawned 31 times over 90 days. Typically, 10 to 12 spawns per fish occurred over 90 to 100 days. During this period, four females (2 to 8 kg) produced an average of 23,400 embryos per fish per day, whereas captive fish (9 to 15 kg) in Texas produced 26,000 embryos per fish per day in 52 spawns over 76 days (Arnold et al. 1977). Arnold's group induced spawning in the fish by using variations in photoperiod and temperature regimes simulating those of different seasons. Fertilization was greater than 99%, with hatching success over 90%. Colura reported 11.4 million fry collected from a single female of unspecified length in a 1893-liter tank over a 2-week period (Anonymous 1979). Nevertheless, optimal conditions seldom, if ever, exist for long periods in nature, and spawning probably occurs during a few week period that presumably differs in length for fish in different regions. A maximal single spawn apparently exists (estimated by Colura as 30,000,000 eggs for a 9 to 14 kg fish) and that over a spawning season is probably somewhat consistent with fecundity values presented earlier. The number of oocytes actually undergoing vitellogenesis and the size at which they

begin that process presumably depend indirectly on temperature, photoperiod, and other factors.

#### *Migration and Estimation of Abundance*

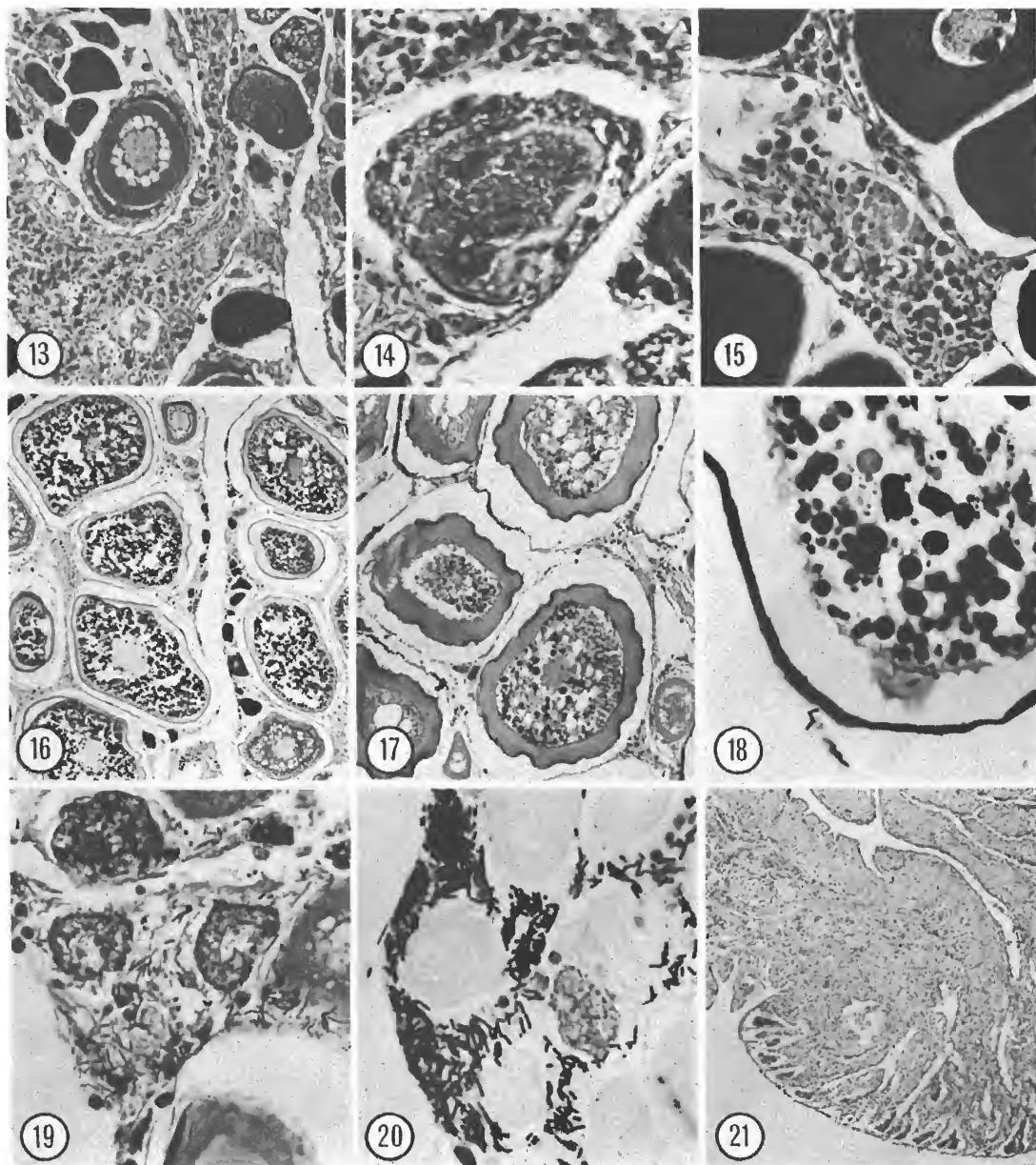
A total of 448 fish were tagged to evaluate migration of the red drum. Those included 88 relatively young individuals from inshore estuarine areas and 360 older ones from near barrier island marine habitats in the Gulf of Mexico. To date, commercial and recreational fishermen returned data on 33 (7.4%) of those tagged fish. Of those, 20 fish 172 to 350 mm SL long were released and recaptured in bayous; four were caught near that site within a week, six were caught there within 47 and 464 days, and the other ten traveled a minimum of 4 to 33 km within 4 to 316 days.

Data from 13 fish tagged offshore suggest a more extensive migration for large offshore fish, especially when followed over a period of time. Four fish about 650 to 850 mm long did not move more than a few km in 4 days, and another was caught in the same area after 4 months. On the other hand, an apparently healthy 690 mm individual moved 16 km into Mississippi Sound within one day. After 92 to 160 days, five fish 790 to about 850 mm long had migrated at least 24 to 63 km westward. Another fish, initially 810 mm long, was caught off a jetty at Galveston, Texas, 778 km westward after 752 days.

Eastward migration was also recorded. A 760 mm long fish moved eastward at least 316 km within 399 days; it was caught near St. Joseph Point, Florida. A fisherman cut open the stomach of a medium-sized individual of a red drum he caught in Mifflin, Alabama, to determine on what it was feeding. There he found a specimen of the spot, *Leiostomus xanthurus* Lacépède, tagged in Davis Bayou, Ocean Springs, 6 days earlier. Depending on whether the drum traveled by a tortuous inland route or along the coastline, the minimum distance traveled was 121 or 156 km. Less likely, of course, is the possibility that the spot traveled a long distance before being eaten.

Another method of estimating migration and estimating abundance involves observations of changes in locations of schools of large fish by commercial fishermen and by pilots that have training in spotting menhaden and other fish for commercial purposes. A compilation of their observations, observations that agree with ours, provide the following scenario. Adult red drum occur singly or in schools. When they make major seasonal migrations and during most of the time when in the Gulf of Mexico, they occur in schools. These schools often occur near black drum, Atlantic tarpon, and pompano, at least when near shore. The red drum can

oocytes all in the same field. The separations between oocytes and follicles and among oocytes are postmortem artifacts. 10. Ripening oocytes with yolk and fat vesicles coalescing to form a central "oil droplet." A few dark staining yolk globules can be seen, but most had already fused to form the lighter staining yolk material. 11. A spent ovary in October showing various stages of atretic oocytes, empty follicles, and prominent intralamellar septa. 12. Close-up of ovary in Figure 11 suggesting absorption of atretic oocytes. Note cellular infiltrate that includes numerous PAS-positive granular leukocytes.



Figures 13–21. Sectioned ovarian tissue from *Sciaenops ocellatus*. 13. An atretic oocyte with fat vesicles pressed against irregularly-shaped nucleus. The PAS-positive granular leukocytes surround the atretic oocyte and occur abundantly in adjacent connective tissue. 14. Close-up of degenerated oocyte surrounded by infiltrate including several PAS-positive and two basophilic granular leukocytes. 15. PAS-positive granular leukocytes in connective tissue among “resting oocytes.” They are involved with central mass of necrotic cells still exhibiting pyknotic nuclei. 16. Apparently atypical oocytes with the eosinophilic zona pellucida wider than normal. Even though some postmortem artifacts exist, most of the oocytes in this gravid ovary in late August have a narrow zona pellucida. 17. Oocytes nearby to those in Figure 16 undergoing atresia and exhibiting an especially wide zona pellucida. 18. Similar to Figure 17, but showing the red staining outer layer and yellow staining inner layer when stained using Taylor’s method for bacteria. 19. Degenerating oocytes in different region of same ovary as in Figures



almost always be readily distinguished from those fishes by trained spotters because of its color and because schools of red drum do not randomly intermix with others. When interspecific schools are not separate, mixing is restricted to the respective fringes. When feeding along the shoreline of islands or mainland, they spread out in water having a depth more than 1.2 meters. Rarely have they been observed from the air for more than a 2 hr period. They appear immediately prior to low tide up to the flood tide, but never during the slack of high tide. Individuals from most schools typically weigh between 5 and 15 kg.

Schools occasionally group tightly. The largest observed compact school also included black drum and tarpon and occupied an 8 hectare area in and around Cat Island Pass. It was estimated conservatively by a pilot and a fisherman at 4.5 million kg, which included 50 to 60% red drum. Large schools of red drum occasionally contain 150,000 to 250,000 fish. On one daily airplane trip, flying over water from the mouth of the Mississippi River, Louisiana, to Mobile Point, Alabama, Timothy Stevens, an experienced menhaden spotter, observed several schools and made a conservative estimate totaling 50 million kg of red and black drum, with 50 to 60% comprising red drum. The total amount from Texas to south Florida and along the Atlantic seaboard must indeed be tremendous. According to two commercial sources, schools in the northern Gulf of Mexico appear to be larger and more numerous during the last 10 years than during the previous 14 or so years.

Large schools of red drum first appear about April. Usually this occurs off Alabama and by the appearance, disappearance, and (re)appearance of similar-sized schools, there tends to be a general migration to Breton Island and Cameron areas of Louisiana. By September or October, the schools disappear offshore, presumably to spawn. A few spent fish appear along the beaches in October and November. During summer months, schools often spread out more than during spring and autumn, occurring all over Mississippi Sound and adjacent regions. Numerous fish occur around the mouths of the Pascagoula River and various bayous.

Schools may utilize a portion of the Yucatan current for migration from October to April; their appearance along beaches apparently varied as did the current. While setting purse seines for carangids, commercial fishermen have recently unintentionally caught schools of up to 34,000 kg of red drum underneath those fish at a depth of 37 meters (Anonymous 1982). Ralph Horn, a commercial seafood dealer, says that schools of red drum have been monitored commonly at depths of approximately 40 to 70 meters of

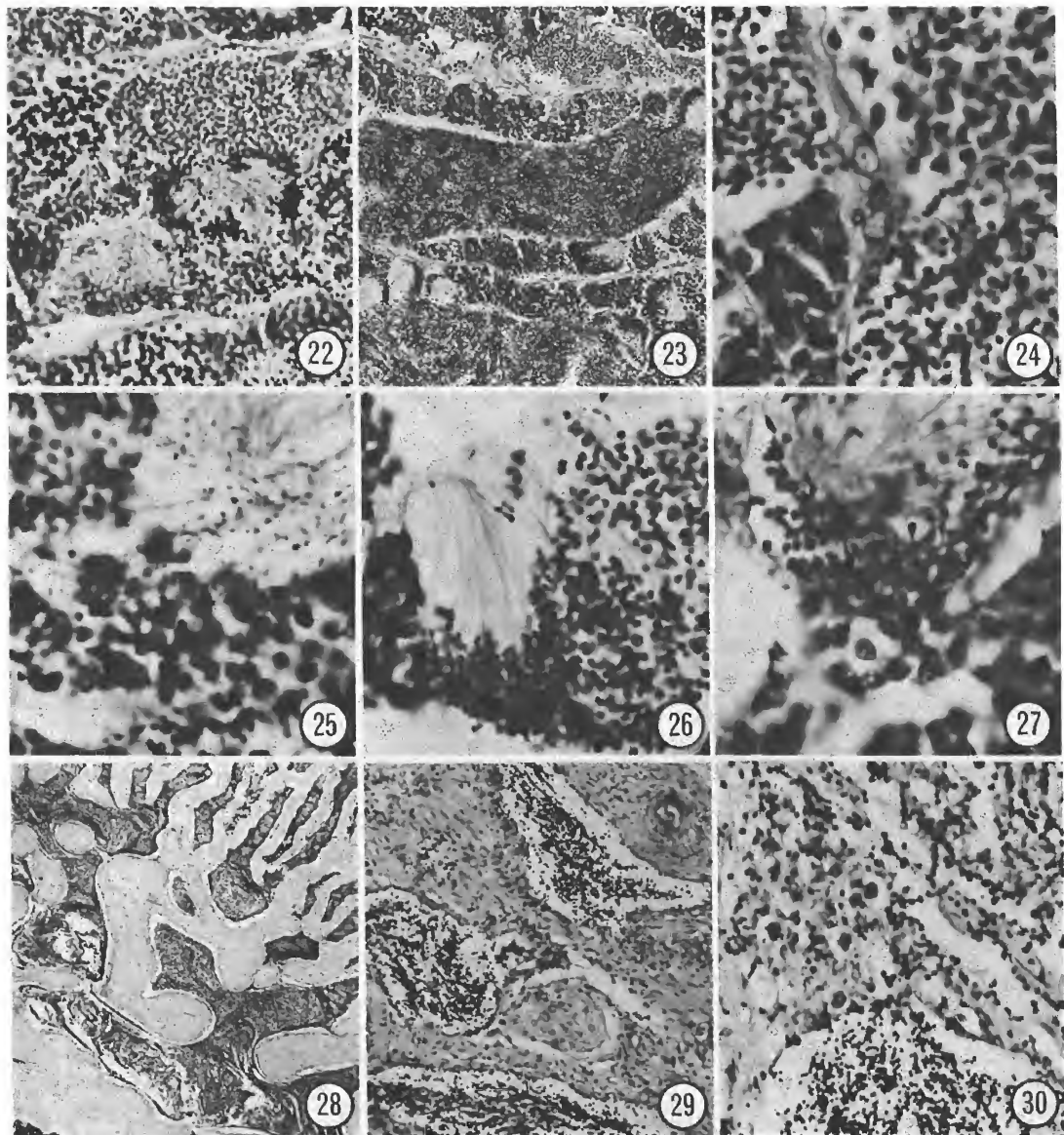
water. Simmons and Breuer (1962) reported schools 19 km offshore.

The above patterns are not presented in most recent literature sources on the red drum, and generally that fish is thought not to undergo extensive migrations (Perret et al. 1980). Data from Mississippi and from all references, however, can be superimposed on the patterns described above. The large sample of returned tagged fish, 47.5% of 690 fish from five Schlitz tagging programs in Florida, produced 91.2% of those recoveries from near the location of release (Beaumariage 1969). Similar results also occurred in Texas (Bryan 1971, Matlock and Weaver 1979) and Louisiana (Adkins et al. 1979). Those and other authors assume no more than a short spawning migration for two primary reasons. First, 1- and 2-year-old fish and occasionally older ones that they tagged probably did not enter the offshore migrating schools. Matlock et al. (1977) reported fish remaining in Texas bays for three to four years to mature before they migrated to the Gulf of Mexico. Second, most older fish appear to remain in one general area for several months, at least during some seasons in the northern Gulf of Mexico. They presumably remain when food is readily available (Overstreet and Heard 1978). The immigration of large fish to near shore and bay areas in spring and migration to the Gulf have been reported in Texas by Pearson (1929), Gunter (1945), Miles (1950), and Simmons and Breuer (1962), although the latter thought the movements might be less pronounced and cover shorter periods. Pearson (1929) thought an apparent decrease in the number of large fish in bays and lagoons during summer could be explained at that time by an increase of power boats, water traffic, and other disturbances by people. Apparent migrations based primarily on catch records and on observations by a menhaden spotter pilot are also reported along the Atlantic coast. Adults apparently move north to North Carolina capes from Florida in spring and south in fall (Yokel 1966). Some of these fish apparently migrate as far as Virginia and into Chesapeake Bay (Yokel 1966), and Welch and Breder (1924) discussed a possible summer migration to New Jersey from the south, arriving in May and remaining until October. Some fish apparently spent winter just south of Cape Hatteras (Pearson 1932, Yokel 1966).

Individual foraging while in estuaries may be considerable, even if a fish remains within a small general area. Carr and Chaney (1976) attached an ultrasonic transmitter to a 3.2 kg fish in the Intracoastal Waterway in Florida. It moved south about 1.6 km within 1½ hrs after release and then 1.2 km north during the next 5½ hrs, always traveling against

16 and 17 showing an infection by a gram negative rod bacterium. The bacterial involvement appeared localized to a general central focus as did the oocytes with the wide zona pellucida (= zona radiata). 20. Taylor's method for bacteria showing small concentration of gram-negative, rod bacterium.

Figure 21. Testis of virgin 333 mm SL specimen of *Sciaenops ocellatus* in May with few spermatozoa in peripheral tubule lumens.



Figures 22–30. Sectioned testicular tissue of *Sclaeenops ocellatus*. 22. Typical area of compact, active, gravid testis in 710 mm SL fish in August showing all stages of development. 23. A different gravid testis than in Figure 17 in August with tubule lumens expanded with spermatozoa. 24. Spermatogonia associated with Sertoli cells. Note vacuolated primary spermatocysts and other stages of spermatogenesis through the spermatid. 25. A composite showing secondary spermatocytes, early (relatively large and light staining) and late (smaller and stained more darkly) spermatids, and flagellated spermatozoa. 26. Germinal cysts with flagellated spermatozoa in middle and flagellated, larger spermatids to the right. Note spermatocytes to the left. 27. Spermatozoa with typical vacuolated spermatocytes near lower portion of field. 28. Post-spawning testis of 665 mm SL fish misdiagnosed as "developing IV" in October. This testis has no actively producing areas, but the lumens are filled with residual spermatozoa. The testes of some other larger fish diagnosed as developing IV in October had few or no spermatozoa. 29. Resting stage of 728 mm SL fish misdiagnosed as "gravid" in October, but filled with considerable residual spermatozoa. 30. One of relative few "active" areas in same testis shown in Figure 29 showing a few PAS-positive granular leukocytes.



tidal flow and entering the mouths of almost every creek encountered. At night, it laid in a deep hole 140 meters up a small creek. Even though a malfunctioning receiver terminated the project on the third day, long-lasting tracking devices should prove rewarding in critically following movements of both young and old fish.

As indicated by tagged 1- and 2-year-old red drum in Mississippi and elsewhere, movements apparently consist mostly of foraging and of responses to temperature and salinity. Recreational fishermen caught large numbers of 0.68 to 0.77 kg fish from protected areas of Back Bay of Biloxi, with the larger ones caught in or near the relatively high salinity of Mississippi Sound (McIlwain 1978). Catches began in summer and increased into autumn.

Fluctuations in the first two year classes are especially apparent because fish grow so rapidly during those years. These depend on several factors, mostly abiotic ones, but also on biotic ones. Of the especially critical abiotic factors, temperature and photoperiod control spawning, temperature controls hatching, currents control dispersal, and a variety of environmental conditions and toxicants affect the health of larvae and juveniles. These latter factors will be discussed in more detail in a later section. Added to these barriers is the amount of available food for the different stages. In the laboratory, larvae required food on day 3 after hatching, at least when fed rotifers, or a reduction occurred in their growth and survival. If not fed by day 5, all fish died, even though survival was prolonged for a few (Roberts, Morey et al. 1978). The location and in some cases number of spawning adults relative to sufficient food and the conditions in estuaries where young develop probably determine local abundance of year-classes.

#### Parasites, Diseases, Mortalities, and Abnormal Conditions

All fish utilized in this study did not undergo a critical examination for parasites. Nevertheless, several were examined as were others before many aspects of this study began. In some cases, only specific or conspicuous parasites were noted. These records as well as records reported by other workers occur in Table 9. Limitations concerning these records are the same as discussed for *Cynoscion nebulosus* (see Overstreet 1983).

Several microbial organisms also occur in or infect the red drum. Most of these have not been identified or reported. One agent that has produced epizootics occurred along the Texas coast. This anaerobic bacterium, either or closely related to *Eubacterium tarantellus* Udey, Young, and Sallman 1977, caused the red drum to become disoriented and swim in an uncoordinated manner (Henley and Lewis 1976). The infection that localized in part of the ovary of a fish in the present study (Figures 19–20) probably had little influence on the host's health, but others involved with secondary infections may. Some red drum from ponds in Alabama had the pathogenic *Vibrio anguillarum* Bergman 1909 in kidney

and liver tissue, *Aeromonas hydrophila* (Chester) from kidney tissue and a lesion, and an unidentified light-brownish colored fungus on gills, skin, and fins (Trimble 1979). Colura (personal communication) found vibriosis in red drum in Texas (Palacios) ponds, and that or other bacteria killed many fingerlings in the same ponds at a later date when reared in fresh water from a well containing less than 15 ppm  $\text{CaCO}_3$  but not when in water from a different well with a higher concentration of  $\text{CaCO}_3$  (Stickney and Davis 1982).

Red drum in Mississippi Sound and associated bayous and probably most other estuarine regions where it lives is susceptible to many of the same or similar parasites and diseases as the spotted seatrout (e.g., Figure 33, Overstreet 1983). Figure 34 shows a ciliate and Figure 35 shows an isopod, both infesting and harming young fish from a bayou. Overstreet (1983) discussed the apparent effect by that isopod on the seatrout. Some of the adult copepods can also damage gill tissue (e.g., Causey 1953b), whereas the chlamydia can harm larval and postlarval fish (Overstreet 1983) (Figure 36). The red drum also is vulnerable to additional diseases and stresses not normally encountered by seatrout, especially when in the Gulf of Mexico with its relatively high salinity. One atypical case involved a barnacle, *Balanus improvisus*, which covered the epithelium of much of the flanks in four areas on the right side and three larger areas on the left side of a 642 mm SL fish and exhibited associated inflamed lesions (Figures 37–38). The single infested red drum was caught in a trammel net along with black drum and striped mullet at Marsh Point, Ocean Springs, on 20 March 1980. Perhaps the initial set of larvae or even all the barnacles attached to areas abraded from a net or some other source and then subsequently caused further inflammation and secondary infection. *Balanus improvisus*, a species that can live in brackish water, typically occurs on rocks, wood, shore installations, ships, and molluscan shells, but has been reported from algae, crustaceans, and fish (Henry and McLaughlin 1975).

An unknown condition or conditions kill many large drum. Possible explanations occur for many cases. As an example, on 18 May 1979, 125 specimens of dead red drum were examined; they had washed ashore onto Petit Bois and Horn islands. They measured  $86 \pm 5$  cm SL, their gills were pale, and they appeared to have died a few days earlier. No other species of dead fish were observed. Fishermen called GCRL to complain that on 17 May about 400 such fish occurred floating up to a distance of 1.5 km from shore. According to Thomas McIlwain (personal communication) a mass of water with high salinity, low temperature, and low concentration of dissolved oxygen (0.7 ppm) which could explain these deaths with pale gills was identified on the bottom south of the barrier islands at that time. In September 1969 during a period characterized by 30°C water containing organic pollution, with a low concentration of dissolved oxygen (0.0 to 0.6 ppm) and variation in salinity

throughout the water column, 320 red drum 300 to 600 mm TL plus large numbers of other fishes died in the Arroyo Colorado in Texas (Bryan 1971).

The 3 July 1983 *The Times-Picayune/The States-Item* (New Orleans) showed a picture of a large red drum that was apparently one of thousands that had died from an unknown cause and washed ashore along a 16 km stretch of Padre and Mustang islands in Texas. Over the years, commercial fishermen have talked about many thousands of floating dead red drum in the Gulf of Mexico or adjacent waters that they thought had died from "red tide" or some other factor. When local people recall mass mortalities, they often mention ones limited to red drum, as are some of those mortalities indicated above. Kenneth Melvin (personal communication) reported to me another such case restricted to red drum, but these fish, about 2,000 in number, were fingerlings; these dead fish were floating off Bellefontaine Point near Ocean Springs on 25 July 1978. Cause for some "mysterious" deaths can be assumed, such as those resulting from freshwater that accompanied the opening of the Bonnet Carré Spillway in 1973 to relieve water pressure on Mississippi River levees and those resulting from rapidly decreasing temperatures in January 1977 and February 1978 (Adkins et al. 1979, Kenneth Melvin, personal communication).

The red drum can survive most environmental conditions tolerated by hardy fishes. In summary from Simmons and Breuer (1962), they live in fresh water to that with at least 50 ppt, but as adults they occur most abundantly in 30 to 35 ppt. The red drum has been observed in 2 to 33°C in natural waters, but it moves into deep water when extreme temperatures occur. Like seatrout and most fishes (Gunter 1941, Overstreet 1974, 1983) it cannot withstand a rapid drop in temperature. Small juveniles are probably more sensitive to cold than large ones (Moore 1976). Because of the habits of young fish, they are especially vulnerable to environmental stresses. On one occasion, Bryan (1971) counted over 1,100 dead first year red drum trapped around the base of a dam on the Cayo Atascosa in Texas which had been established to impound water in winter. Juvenile fishes entered the impoundment each spring seeking low saline water. Of those that became established near the dam in summer during low tides, some or all frequently became trapped and died in the resulting hot stagnant water. Actually, more potentially stressful conditions occur for both adults and juveniles in estuaries and in culture conditions than in the Gulf of Mexico.

Eggs and larvae are especially vulnerable to environmental conditions. Eggs are fertilized and hatch favorably at 30 ppt at 22 to 23°C, and larvae developed favorably in 23 to 25°C (Holt, Johnson et al. 1981). When reared at 30°C, the yolk-sac stage lasted 40 hr compared to 84 hr at 20°C. The optimum condition for both hatching and 24 hr survival was determined to be 30 ppt at 25°C (Holt, Godbout, and Arnold 1981). That study showed the importance of a high salinity concentration for both hatching and survival during the first 24 hr, if the temperature was not 25°C. The acceptable salinity range of 10 to 40 ppt at 25°C decreased to a range of 5 to 30 ppt with a corresponding decrease in hatching as the temperature varied from 25°C. Below 25 ppt, eggs sank to the bottom. Salinity played little role in 2-week survival of the larva, but temperature became increasingly important as the larva developed. Assuming that spawning typically occurred in water with a high salinity, Holt, Godbout, and Arnold (1981) pointed out that spawning success and subsequent strength of the resulting year-class of fish can be adversely affected by early onset of seasonal low temperatures. Fingerlings as small as 40 mm TL introduced into freshwater over a 3 hr period survived, but showed stress; those 125 to 140 mm TL showed little or no stress (Lasswell et al. 1977). Temperature and salinity combinations that cannot be tolerated by fry and fingerlings have not been well established, but, as suggested earlier, such combinations probably influence greatly the abundance of a year class.

All sizes of fish are sensitive to high salinities combined with high temperature, but to a different degree (Simmons 1957). In the Laguna Madre of Texas, individuals of red drum 13 to 23 cm long occurred abundantly in the upper area, provided that the salinity there was not above 45 ppt. Populations in Texas were severely limited by 50 ppt (Simmons 1957). Juveniles stocked into ponds receiving heated discharge water from a power plant near Baytown, Texas, grew well and survived in water up to 35°C (Luebke and Strawn 1973). Some fish, however, apparently died from handling stress followed by introduction of 39°C water to refill a pond. Fry in ponds cannot survive low dissolved oxygen concentrations of 0.6 to 1.8 ppm (Colura et al. 1976). As mentioned above, when water masses with unusually low dissolved oxygen concentration develop, even in the Gulf of Mexico, numerous adult fish apparently succumb before avoiding the poor conditions. Simmons and Breuer (1962) and Davis (1980) suggested that environmental

Figures 31–39. Micrographs showing testes and symbionts of *Sciaenops ocellatus*. 31. Close-up of an area with germinal cells in same testis shown in Figure 29. 32. Inflammatory focus in developing IV, 855 mm SL fish in April, showing an abundance of PAS-positive granular leukocytes and lymphocytes as well as four giant multinucleate cells. 33. A 1.67 mm long metacystode phase of *Rhineboothrium* sp. occurring in the lumen of the intestine and causing no harm to the fish host. 34. A rather heavy trichodinid ciliate infestation on a gill lamella of a juvenile red drum that had just been caught in a bayou. 35. The isopod *Liromeca ovalis* eroding the gills of a juvenile red drum from a marsh. 36. A larval caligid attached by its frontal filament to the base of the dorsal fin of a 9 mm SL postlarval red drum. Another copepod occurred in the dorsum. 37. Rear portion of a red drum with "fin-rot syndrome" and an infestation of *Balanus improvisus* attached to epithelium overlying scales. Note the multiple ocelli on the fish. 38. Close-up of Figure 36 showing barnacles and inflammation. 39. Larval specimen of the nematode *Contracaecum multipapillatum* encapsulated along periphery of liver.

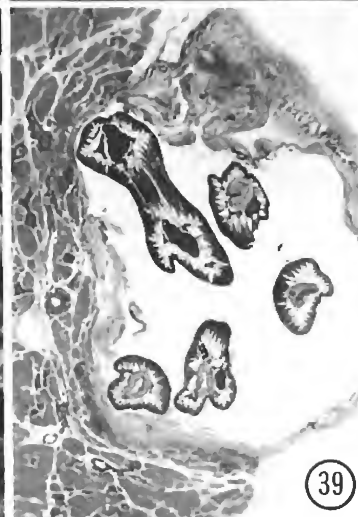
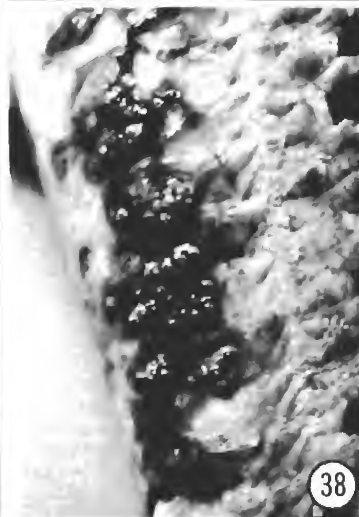
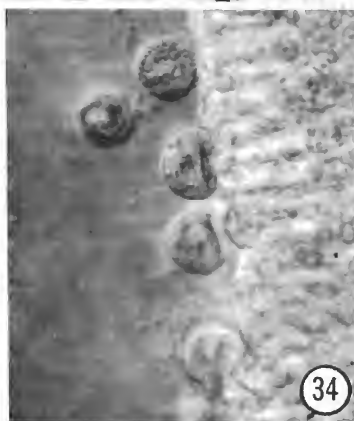
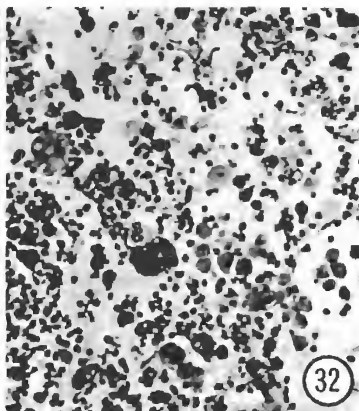
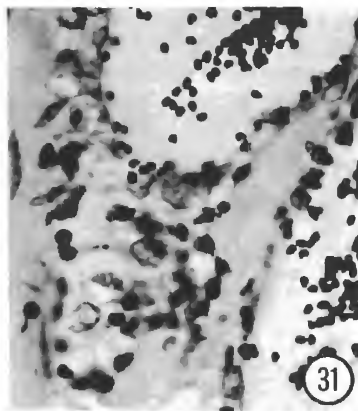


TABLE 9.  
Partial list of parasites from *Sciaenops ocellatus*.

Parasite	Site	Geographical locality	Reference
Sarcomastigophora			
Blastodidiidae			
<i>Amyloodinium ocellatum</i> (Brown 1931)	Gills and skin	Alabama (ponds)	Trimble (1979)
	Gills	Experimental infection	Lawler (1980)
Cryptobiidae			
<i>Cryptobia</i> sp.	Gills	Alabama (ponds)	John Hawke (Personal communication)
Microspora			
Microsporidia			
<i>Pleistophora</i> sp.	Liver	Mississippi	Present study
Ciliophora			
Hymenostomatia			
<i>Cryptocaryon irritans</i> Brown 1951	Gills, body	Palacios, TX (ponds)	Colura (Personal communication)
Peritrichia			
<i>Trichodina</i> spp.	Gills, fins, skin	Alabama (ponds)	Trimble (1979)
		Mississippi, St. Marks, FL,	Present study
		Palacios, TX (ponds)	
<i>Tripartiella obliqua</i> Lom 1963	Gills	Alabama (ponds)	Trimble (1979)
<i>Ambiprya</i> sp.	External	Alabama (ponds)	Trimble (1979)
Myxozoa			
Myxosporea			
<i>Henneya ocellata</i> Iversen and Yokel 1963	Intestinal and cecal epithelium	Beaufort, NC; Everglades National Park, FL	Linton (1905), Iversen and Yokel (1963)
Cestoda			
Tetraphyllidea			
"Scolex polymorphus"	Intestine, pyloric ceca	North Carolina	Linton (1905)
"Scolex spp., type large"	Intestine, pyloric ceca	Mississippi	Present study
"Scolex spp., type small"	Intestine, rectum	Mississippi	Present study
<i>Rhinebothrium</i> sp.	Intestine	Mississippi, St. Marks, FL	Present study
Tetrahynchea			
<i>Poecilancistrum caryophyllum</i> (Diesing 1950) (also as <i>P. robustum</i> )	Muscle	Florida	Hutton (1964)
		Texas	Schlicht and McFarland (1967)
		Mississippi	Overstreet (1977, 1978)
"Spaghetti worm" similar to <i>P. robustum</i>	Muscle	Laguna Madre, TX	Simmons and Breuer (1962)
Monogenea			
Udonellidae			
<i>Udonella caligorum</i> Johnston 1835		Palacios, TX (pond)	Present study
Spoiled specimens		Port Aransas, TX	Koratha (1955)
Digenea			
Acanthocolpidae			
" <i>Stephanostomum tenue</i> "		Beaufort, NC	Linton (1905)
Aporocotylidae			
<i>Cardicola</i> sp.	Heart, branchial vessels	Mississippi	Overstreet and Lawler, Present study
Bucephalidae			
<i>Bucephaloides megacirrus</i> Riggan and Sparks 1962	Intestine	Grand Isle, LA; Alligator Harbor, FL	Sparks (1958), Loftin (1960), Riggan and Sparks (1962)
	Pyloric ceca and intestine	West Florida	Hutton (1964), Nahhas and Short (1965)
		Barataria Bay, LA; Mississippi	Corkum (1968), Present study
Cryptogonimidae			
<i>Metadena spectanda</i> Travassos, Freitas, and Bührnheim 1967	Intestine, pyloric ceca	Mississippi, Palacios, TX (pond)	Present study
<i>Metadena spectanda</i> metacercaria	Fins	Mississippi	Present study

TABLE 9 (Continued)  
Partial list of parasites from *Sciaenops ocellatus*.

Parasite	Site	Geographical locality	Reference
Didymozoidae			
Metacercaria	Intestine, body cavity	Mississippi; St. Marks, FL	Present study
Hemiuridae			
<i>Lecithochirium mecosaccum</i> Manter 1947	Stomach	Alligator Harbor, FL	Nahhas and Short (1965)
<i>Stomachicola rubea</i> (Linton 1910)	Encysted in muscle tissue	Sapelo Island, GA	Sinclair et al. (1972)
Lepocreadiidae			
" <i>Lepocreadium areolatum</i> "		Beaufort, NC	Linton (1905)
Opecoelidae			
<i>Opecoeloides fimbriatus</i> (Linton 1934) (as <i>Fimbriatus</i> f.)	Intestine	Alligator Harbor; Mud Cove; St. George Island, FL	Nahhas and Short (1965)
(as <i>Distomum vitellosum</i> in 1905)		Grand Isle, LA	Sparks (1958)
<i>Opecoeloides vitellosus</i> (Linton 1900)		Experimental	Hutton (1964)
Unidentified larva	Rectum	Beaufort, NC	Linton (1905, 1934)
		St. Marks, FL	Present study
		Everglades National Park, near Chokoloskee, FL	Yokel (1966)
Acanthocephala			
Polymorphidae			
Polymorphid cystacanth	Mesentery	Mississippi	Present study <sup>1</sup>
<i>Southwellina hispida</i> (VanCleave 1925) cystacanth	Mesentery and embedded in gonad	Mississippi	Present study <sup>1</sup>
Nematoda			
Anisakidae			
<i>Hysterothylacium reliquens</i> (Norris and Overstreet 1975)	Stomach and intestine	Northern Gulf of Mexico 30°10'N, 87°45'W, 11 meters, Mississippi Sound	Deardorff and Overstreet (1981 a), Present study
" <i>Ascaris</i> sp."	Digestive tract?	Sandy Hook, NJ	Linton (1901)
? <i>Hysterothylacium reliquens</i> larva	Mesentery	Mississippi	Deardorff and Overstreet (1981b)
" <i>Ascaris</i> sp." immature	Peritoneum	Woods Hole Region	Linton (1901)
<i>Goezia pelagia</i> Deardorff and Overstreet 1980	Intestine	Mississippi	Present study
<i>Goezia</i> sp.		Palacios, TX (pond)	Deardorff and Overstreet (1980a)
<i>Contracaecum multipapillatum</i> (von Drasche 1882) larva	Mesentery	Mississippi	Deardorff and Overstreet (1980b)
	Kidney, liver, other visceral tissue	Mississippi, Everglades National Park	Present study
" <i>Contracaecum collieri</i> "		South Carolina?	Lawler (1978)
<i>Contracaecum</i> sp.	Mesentery of gut	Everglades National Park	Hutton (1964), Yokel (1966)
Camallanidae			
<i>Spirocamallanus cricotus</i> Fusco and Overstreet 1978	Intestine	Mississippi	Present study
Cucullanidae			
<i>Dichelyne fastigatus</i> Chandler 1935	Intestine	Galveston Bay, TX	Chandler (1935)
" <i>Dichelyne lintoni</i> (Barreto 1922)"		North Carolina	Lawler (1978)
<i>Dichelyne</i> sp. (as <i>Heterakis</i> sp.)		Beaufort, NC	Linton (1905)
<i>Dichelyne</i> sp.	Intestine	Mississippi	Present study
"Small roundworm"	Ovary - egg cases	Texas	Elam (1971)
Annelida			
Hirudinea			
Piscicolidae			
<i>Calliobdella vivida</i> (Verrill 1872)	Mouth cavity	Mississippi	Present study
<i>Myzobdella lugubris</i> Leidy 1851	Mouth cavity, branchial cavity	Mississippi	Sawyer et al. (1975)
Branchiura			
Argulidae			
<i>Argulus bicolor</i> Bere 1936	Fins	Mississippi	Present study <sup>2</sup>

TABLE 9 (Continued)  
Partial list of parasites from *Sciaenops ocellatus*.

Parasite	Site	Geographical locality	Reference
<b>Copepoda</b>			
<b>Anthosomidae</b>			
<i>Lernanthropus longipes</i> Wilson 1932		Beaufort, NC	Pearse (1948, 1952)
<i>Lernanthropus paenulatus</i> Wilson 1922	Gill	Texas	Causey (1953b)
<i>Lernanthropus</i> sp.	Gill	Mississippi	Present study <sup>2</sup>
<b>Caligidae</b>			
<i>Caligus annularis</i> Yamaguti, 1954	Mouth	Sapelo Island, GA	Present study <sup>3</sup>
<i>Caligus bonito</i> Wilson 1905	Body	Upper Laguna Madre, TX	Simmons (1957), Simmons and Breuer (1962)
<i>Caligus haemulonis</i> Krøyer 1836 (as <i>C. haemuronis</i> )	Mouth	Texas, Grand Isle, LA	Pearse (1952), Causey (1953a, 1953b)
<i>Caligus latifrons</i> Wilson 1905		Upper Laguna Madre, TX	Simmons and Breuer (1962)
<i>Caligus mutabilis</i> Wilson 1905		Beaufort, NC	Pearse (1948)
<i>Caligus rapax</i> Edwards 1840 (as <i>C. repax</i> )		Upper Laguna Madre, TX	Simmons (1957), Simmons and Breuer (1962)
<i>Caligus sciaenops</i> Pearse 1952a	Gills	Texas	Pearse (1952)
<i>Echetus typicus</i> Krøyer 1864	Gills, branchial cavity, operculum	New Orleans, LA Port Aransas, TX, Grand Isle, LA West Florida Texas North Carolina to Apalachee Bay, FL	Krøyer (1864) Causey (1953a, 1953b, 1955) Bere (1936) Pearse (1952) Ho (1966), Yokel (1966)
<i>Sciaenophilus tenuis</i> van Beneden 1852	Gills	Mississippi	Present study
<i>Lepeophtheirus</i> cf. <i>longipes</i> Wilson, 1905	Gills	Mississippi	Present study <sup>2</sup>
<b>Lernaeopodidae</b>			
<i>Neobrachiella gulosa</i> (Wilson 1915) comb. n. (previously as <i>Brachiella</i> g.)	Gills, branchial cavity, and under operculum	Wilmington, NC Sapelo Island, GA New York-Texas  Texas  Grand Isle, LA West Florida	Yokel (1966) Present study <sup>2</sup> Wilson (1915, 1932), Ho (1977) Causey (1953b, 1955), Simmons and Breuer (1962), Pearse (1952) Causey (1953a) Bere (1936), Hutton (1964), Yokel (1966) Present study
<i>Neobrachiella intermedia</i> (Bere 1936) comb. n. (previously as <i>Brachiella</i> i.)	Gills and inner surface of operculum	Mississippi West Florida Sapelo Island, GA Wilmington, NC	Bere (1936), Yokel (1966) Present study Yokel (1966)
<b>Pennellidae</b>			
<i>Lernaeenicus radiatus</i> (Lesueur 1824)	Dorsal fin	Wilmington, NC Barataria Bay, LA Sapelo Island, GA, Mississippi	Yokel (1966) Hein et al. (1982) Present study <sup>2</sup>
<b>Isopoda</b>			
<b>Cymothoidae</b>			
<i>Anilocera laticauda</i> Edwards 1840		Texas	Pearse (1952)
<i>Lironeca ovalis</i> (Say 1818)	Gills	Mississippi	Present study
<i>Nerocila acuminata</i> Schioedte and Meinert 1910	Dorsal fin	Laguna Madre, TX Mississippi	Simmons and Breuer (1962) Present study
<b>Cirripeda</b>			
<i>Balanus improvisus</i> Darwin, 1854	Scales	Mississippi Sound	Present study <sup>4</sup>

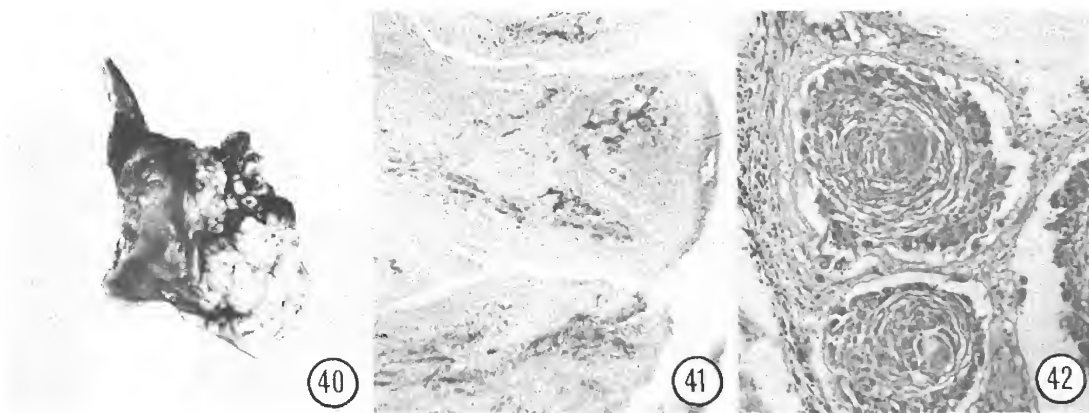
<sup>1</sup>Identified by Gerald D. Schmidt, University of Northern Colorado.

<sup>2</sup>Verified by Z. Kabata, Fisheries Research Board of Canada, Nanaimo, British Columbia.

<sup>3</sup>Identified by Z. Kabata.

<sup>4</sup>Identified by Patsy A. McLaughlin, Florida International University, Miami, Florida.





Figures 40–42. Epidermal papilloma on *Sciaenops ocellatus*. 40. Gross view of 7 by 5 by 4 cm papilloma attached to snout (photo by John Harshbarger, Smithsonian Institution). 41. Low-power view showing papillomatous lesion. The darkly stained spaces are highly vascular fibrotic areas. 42. Medium-power view of pegs of epithelial cells in vertical section.

conditions influenced variations in stocks, at least in Texas and Everglades National Park.

When in culture, the drum can be susceptible to similar diseases that affect the spotted seatrout (Overstreet 1983). *Amyloodinium ocellatum* was held responsible for at least 18% of the mortalities in a study in Alabama (Trimble 1979) and considered the most serious disease agent on red drum in ponds in Palacios, Texas (Colura, personal communication). *Cryptocaryon irritans*, the marine counterpart of *Ichthyophthirius multifiliis* Fouquet 1876 infesting freshwater fishes, also caused mortalities in Texas.

The same parasites that represent a potential public health problem (*Hysterothylacium* type MB larva Deardorff and Overstreet 1981b) and esthetic-economic problems (*Poecilancistrum caryophyllum* and *Stomachicola magna*) in the spotted seatrout may also infect the red drum, but to a lesser degree (e.g., Overstreet 1977, 1983). Additionally, the red drum often has a relatively large, about 2 cm long, conspicuous nematode infecting the kidneys, liver (Figure 39), serosa of alimentary tract, and mesentery. This worm, the juvenile of *Contracaecum multipapillatum*, also infects mullets and causes numerous people to discard or not eat either wormy or all mullet. People typically react the same way with infected red drum, but usually only younger fish exhibit infections. The worm matures in cormorants, pelicans, the anhinga, and at least the Louisiana heron and green heron, and it did not survive or cause pathological responses in tested experimental mammalian hosts. Presumably, it does not harm man (Deardorff and Overstreet 1980b).

Several taxonomic and systematic problems concerning parasites need to be solved. Do all the copepod species of *Caligus* Müller 1785 listed in Table 9 infest the red drum? The finding of *Caligus annularis* represents the only report of that species in other than the Indo-Pacific area, and per-

haps the species also infests several other Atlantic fishes. Before this study, *Neobrachiella gulosa* and *N. intermedia* had been considered in the genus *Brachiella*. Kabata (1979) revised the genus *Brachiella* and erected *Neobrachiella* for several species formerly in *Brachiella*, and the two closely related species from the red drum belong among them. Seldom do closely related sympatric species infest the same individual, as these do, and the factors which allow both to occur together should be investigated. Does more than one nematode species of *Dichelyne* Jägerskiöld 1902 infect the red drum on the basis of one male and an immature female. He noted that the male's ventral sucker was "practically absent." Stromberg and Crites (1972) examined Chandler's material, concluded that it was adequately described, and considered a preanal sucker absent and the intestinal cecum dorsally located. Representative material from Ocean Springs which may or may not be conspecific had a preanal sucker and an intestinal cecum located dorsally, laterally, or ventrally. Specimens of cucullanids from the red drum along the Atlantic and from the Gulf of Mexico coasts need further study. Stromberg and Crites "discarded" the name *D. lintoni* and described *D. bullocki* Stromberg and Crites 1972 for the species from *Fundulus heteroclitus* (Linnaeus) in New Hampshire. I find the same species commonly in *Fundulus grandis* Baird and Girard and *F. similis* (Baird and Girard) in Mississippi, and it differs from that species in the red drum. The digenean *Opecoeloides vitellus* infects the red drum at least at St. Marks, Florida, but the record of that species figured by Linton (1905) is clearly *O. fimbriatus* as later cleared up by Linton (1934). The two species are not conspecific as suggested by Stunkard (1978).

A few anomalous specimens of red drum have been reported. A 686 mm TL fish from Texas had no eyes (Ward

and Gunter 1962). Another specimen appeared eyeless, but had abnormal eyes that were covered with partially translucent skin, perhaps in response to the high salinity water of Laguna Madre, Texas (Gunter 1945, 1956). Also, three specimens caught at different times but from the same general area in Texas had reversed scales (Gunter 1948). The red drum typically has a large black ocellus, or spot, above the lateral line at the base of each side of the caudal peduncle, occasionally with one or a few additional ocelli located anteriorly. Simmons and Breuer (1962) counted 219 ocelli on one fish; the fish with the attached barnacles in this study had 35 on the right side and 30 on the left. Several adult fish being tagged had regenerated portions of their caudal fins. A few other fish being tagged had a golden coloration. Rather than anomalous, I considered that coloration a normal result, perhaps metabolic in nature, from having recently spent time in low salinity or fresh water. I have noticed that the tarpon, *Megalops atlantica* Valenciennes, from fresh water in southern Florida had a similar golden color, whereas individuals from salt water appeared silvery. A courting male red drum has a different coloration than a female or noncourting male. Above the lateral line, the body becomes dark red to bluish-gray and below that line it becomes pale (Arnold et al. 1977).

The red drum is susceptible to tumors. In 1978, A. G. Johnson sent to the Smithsonian Institution a portion of the snout of a fish caught by Gerald P. Kershner at St. Andrews State Park, Panama City, Florida, with a benign epidermal papilloma (RTL 1904). Well-differentiated epi-

dermal cells extended as pegs and crypts into the dermis (Figures 40–42). A basal cell boundary of these extensions with the intervening connective tissue of the dermis suggests that invasion had not taken place and that the neoplasm was not malignant. Additionally, Elam (1971) found, but did not examine, large tumors in the ovaries collected from two spawning females in Texas.

#### ACKNOWLEDGMENTS

I gratefully acknowledge the following people from GCRL who aided considerably in different aspects of this study: Ronnie G. Palmer, Rena Krol, Joan Durfee, Kay Richards, John Lamb, Roswitha Buxton, Richard Heard, Adrian Lawler, Tom Mattis, Donald Bump, James Carter, Mobashir Solangi, Joanne Laroche, Kenneth Melvin, Lucia O'Toole, Jerima King, Valerie Hebert, Lois Coquet, and Helen Carroll. Several other people involved with the red drum or with the fishing industry also helped. Among these are Robert Colura, Daniel Roberts, Jr., Charles Cowart, Hulst Seafood, Ralph and Douglas Horn, Timothy Stevens, Martin Young, and Hermes Hague. Drs. Allyn G. Johnson and John C. Harshbarger allowed me to report their material and observations concerning the papilloma; Drs. Z. Kabata and Patsy McLaughlin willingly identified some of the crustaceans and Dr. Gerald Schmidt identified the acanthocephalans indicated in Table 9. The study was conducted in cooperation with the U.S. Department of Commerce, NOAA, National Marine Fisheries Service, under PL 88–309, Projects 2–325–R, 2–382–R, and 2–393–R.

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